



UNIVERSITY OF NAIROBI

SCHOOL OF COMPUTING AND INFORMATICS

**MULTI-AGENT BASED RISK MANAGEMENT
PLATFORM FOR SMALL AND MICRO-
ENTERPRISE BUSINESSES IN KENYA**

BY

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Science

Declaration

DECLARATION BY THE STUDENT

I, Raymond Simbi Isiaho, wish to confirm that this research project and the work presented in it is my original work and has not been presented for any other University award.

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The project has been submitted as part fulfilment of requirements for the Masters of Science in Information Systems of the University of Nairobi with my approval as the University supervisor.

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Abstract

All businesses face uncertainty and the challenge for business owners are to determine how much uncertainty to accept as they strive to grow their businesses. Uncertainty presents both risk and opportunity, with the potential to erode or enhance value. In Kenya, Small and microenterprise businesses are exposed to risks all the time and every business is subject to possible losses from unmanaged risks. Such risks can directly affect day-to-day operations, decrease revenue or increase expenses for the business. Their impact may be serious enough for the business to fail.

Currently available risk management solutions are not readily available to Small and micro-enterprise businesses in Kenya. This is partly due to their high cost, accessibility and complexity. In an attempt to solve this problem, A Multi-agent Risk Management system for SMEs in Kenya is presented in this document. The system is intended to be capable of automatically and dynamically assisting small and micro enterprises in Kenya by automatically generating business risk profiles based on business context and information provided on the business as well as dynamically providing timely advice on recommendations to mitigate business risks that would potentially affect SMEs' sustainability through a cheaper and efficient method.

We take outstanding advantage of the following intrinsic characteristics of multi-agent systems in order to develop the proposed solution: (i) autonomy, (ii) social ability, (iii) reactivity and (iv) temporal continuity.

The results show that, increase in sales margins and profit, reduced losses and business sustainability can be achieved through a multiagent system. This is achieved by assigning agents to source business targets (objectives), perform risk assessment to identify risks inherent that would likely impact on the achievement of the identified targets (objectives), recommending required mitigating options to be applied by the SME proprietor and tracking the performance of the business targets (objectives) over time. The study recommends porting of the system into a mobile platform and piloting it in Kenya's informal ("Jua Kali") sector to inculcate proactive risk management in small and microenterprise business to assure their growth, profitability and sustainability.

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LIST OF ABBREVIATIONS

Agent:	A special software component that has autonomy that provides an interoperable interface to an arbitrary system and/or behaves like a human agent, working for some clients in pursuit of its own agenda
CBR	Case Based Reasoning
COSO	Committee of Sponsoring Organizations of the Treadway Commission
FIPA	Foundation for Intelligent Physical Agents
ISO	International Standards Organization
JADE	Java Agent Development Framework
MAS	Multiagent System
SME	Small and Medium Size Business
Risk	The effect of uncertainty on an organization's objectives

CHAPTER 1: INTRODUCTION

Risk Management, is a broad term for the business discipline that protects the assets and profits of an organization by reducing the potential for loss before it occurs, mitigating the impact of a loss if it occurs, and executing a swift recovery after a loss occurs. This involves a series of steps that include risk **identification**, the **measurement** and **evaluation** of exposures, exposure reduction or elimination, risk reporting, and risk transfer and/or financing for losses that may occur.

Enterprise risk management encompasses:

- *Aligning risk appetite and strategy* – business owners consider the business’ risk appetite in evaluating strategic alternatives, setting related objectives, and developing mechanisms to manage related risks.
- *Enhancing risk response decisions* –risk management provides the rigor to identify and select among alternative risk responses – risk avoidance, reduction, sharing, and acceptance.
- *Reducing operational surprises and losses* – businesses gain enhanced capability to identify potential events and establish responses, reducing surprises and associated costs or losses.
- *Seizing opportunities* – By considering a full range of potential events, business owners are positioned to identify and proactively realize opportunities.
- *Improving deployment of capital* – Obtaining robust risk information allows business owners to effectively assess overall capital needs and enhance capital allocation.

All businesses face uncertainty and the challenge for business owners are to determine how much uncertainty to accept as they strive to grow their businesses. Uncertainty presents both risk and opportunity, with the potential to erode or enhance value. Risk management enables management to effectively deal with uncertainty and associated risk

and opportunity, enhancing the capacity to build value, Committee of Sponsoring Organizations of the Treadway Commission (2004).

The underlying premise of enterprise risk management is that every entity exists to provide value for its stakeholders. Small and microenterprise businesses are exposed to risks all the time and every business is subject to possible losses from unmanaged risks. Such risks can directly affect day-to-day operations, decrease revenue or increase expenses for the business. Their impact may be serious enough for the business to fail. Most business owners know instinctively that they should have insurance policies to cover risks to life and property. However, there are many other risks that all businesses face, some of which are overlooked or ignored. For example, businesses face risks to the value of their company through changes in the stock market, they face penalties when they do not comply with regulatory requirements, and they also face risks based on currency fluctuations if they rely on external suppliers or customers. Businesses thus need to anticipate, mitigate and manage their risks on an ongoing basis to safeguard growth, to protect a business' wealth and continued viability.

SMEs in Kenya stand to benefit greatly from efficient and consistent methods for managing business risks. These include the benefits outlined below as suggested by CPA Australia (2009) Risk management guide for small to medium businesses.

- lower insurance premiums;
- reduced chance that the business may be the target of legal action;
- reduced losses of cash or stock etc.;
- reduced business down time.

Intelligent Applications including machine learning, natural language processing and Expert Systems can be used to model, understand and control risk. Applying business intelligence approaches specific for Small and Medium Enterprises risk management and prediction would help SME businesses in Kenya to protect their assets and profits by reducing potential for losses before they occur, mitigating the impact of loss if it occurs and executing swift recovery of it occurs.

Currently available risk management solutions are not readily available to Small and micro-enterprise businesses in Kenya. This is partly due to their high cost, accessibility and complexity. This project thus aims to create a multiagent based platform specific for Small and microenterprises to assist them in applying risk management and prediction on an ongoing basis while ensuring business growth and sustainability.

The Process Flow below describes the proposed system:

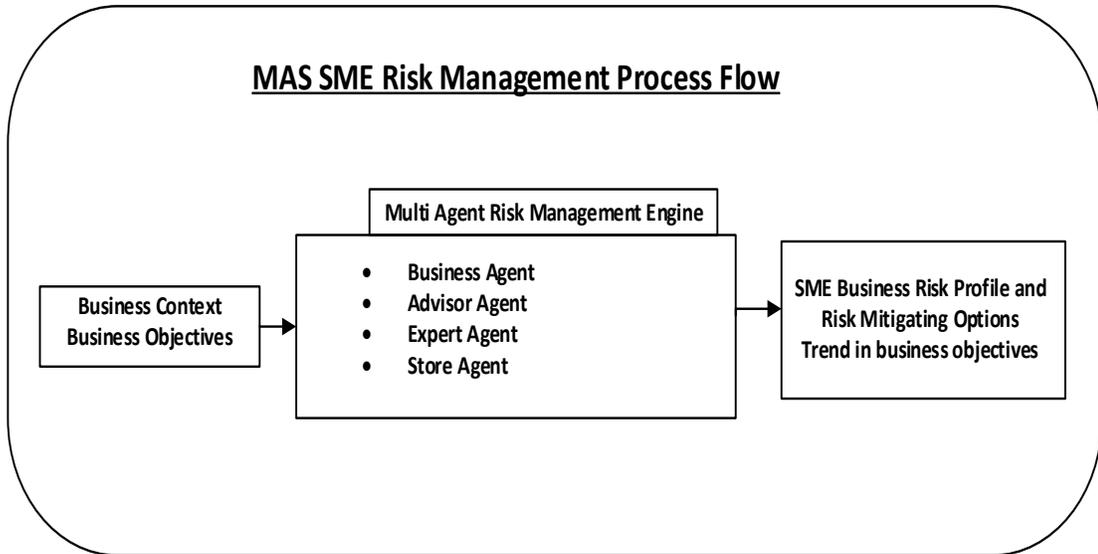


Figure 1-1: Process Flow for MAS Based Risk Management System.

1.1 PROBLEM STATEMENT

Small and Micro Enterprises (SMEs) play an important economic role in Kenya. According to the Kenya Economic Survey 2012, SMEs contributed over 80.8 percent of new jobs created in 2011. The SME sector provides employment for substantially more people than does the formal sector but despite their significance, SMEs in Kenya are faced with the threat of failure with statistics indicating that three out five fail within the first few months, Michael Bowen, et al (2005). This is because starting and operating a small business includes a possibility of success as well as failure. Such reasons for failure can easily be linked to inadequate risk management procedures by SME business owners. Because of the small size of an SME, a simple management mistake, unmanaged challenges or uncertainties are likely to lead to their sure death hence no opportunity to learn from its past mistakes. Such challenges faced by SMEs could be internal and external and may affect SMEs abilities to achieve their objectives. John Shortreed (2010), Enterprise risk management and ISO 31000, the effect of uncertainty on an organization's objectives is "risk."

The Government of Kenya has hinged the achievement of Kenya's Vision 2013 objectives partly on Small and Medium Enterprises. One of the flagship projects for the achievement of the Kenya Vision 2030 strategic objectives is the development and creation of at least 5 SME industrial Parks. Small to medium businesses are however exposed to risks all the time, CPA Australia (2009). It is thus important that efficient and less expensive methods for SME risk management are devised to anticipate and assist the achievement of the Kenya Vision 2030s flagship project for development and creation of the SME industrial parks.

1.2 PROJECT JUSTIFICATION

Small and Micro Enterprise (SME) owner-managers are largely ignorant about the risks faced by their enterprises Yolande Smit (2012). They respond reactively to risk by utilizing risk avoidance and risk transfer techniques. These non-structured approaches to

risk impede on SME growth and success, limiting their role to providing employment, contributing to investment, and contributing to the economy as a whole.

Unlike businesses and organizations operating in regulated environments, e.g. banks, insurance companies, etc. that are required by the regulators to report on their internal control and risk management systems, hence having formal systems and methods for managing risk, SMEs are not often required to formally manage their risks. Furthermore, it would be costly and hence not feasible for SMEs to employ risk management experts to manage risks within their business.

The above leaves SMEs at a disadvantage and possible losses from unmanaged risks. To improve their chance of success and survival, SMEs would benefit from an alternative method to effectively anticipate and manage risks that may threaten their survival by predicting risky situations and providing the necessary mitigating measures to help SMEs safeguard their businesses.

We propose a multi-agent system specifically designed to detect risky situations and provide recommendations to business owners of SMEs.

1.3 OBJECTIVES OF THE STUDY

The main objective of this project is to create a multiagent based risk management system designed to assist small and medium sized business in Kenya to better manage their business risks.

1.3.1 SPECIFIC OBJECTIVES

The specific objectives of the project are;

- Identify basic key metrics required for successful performance and sustainability of small and microenterprise businesses in Kenya;
- Identify risks that would impact SMEs in Kenya from achieving the identified basic key metrics;

- Identify optimal mitigating options to the risks identified;
- Develop a prototype solution, based on Multi-agent systems to help SMEs to reduce the risks identified by predicting undesirable situations and providing recommendations based on previous experiences.

1.4 RESEARCH QUESTIONS

The proposed study was be guided by the following key research questions:

1. What is the possibility of using a multiagent platform for dynamic risk management for SMEs in Kenya?
2. How will the system's success be measured in predicting business risks in Kenyan based SMEs?

1.5 RESEACH OUTCOMES

The outcome of the project undertaking is of major significance because:

- We will develop a solution that will efficiently assist risk management and prediction for small and microenterprise businesses in Kenya at a cheaper cost.
- The resultant multi-agent system will act as a framework for further research efforts on risk management for small businesses based on artificial intelligence.
- It will facilitate risk aware decision making for small businesses in Kenya and help to inculcate risk intelligence into the running of such businesses.

1.6 SCOPE OF THE STUDY

The study is limited to developing a multi-agent Risk Management System for Small and Medium Enterprises in Kenya. This entails performing risk assessment based on a small set of business objectives, dynamically assessing possible risks that will inhibit a small business from achieving the selected objectives, analysing and measuring the risk and identifying the required mitigating measures to be applied. Due to time constraints for creating and testing an inference engine for various industry sectors of businesses in Kenya, the prototype will demonstrate the use of agents in a limited number of industry

sectors. However, the prototype can be used both in all other industry sectors where small businesses operate in Kenya.

1.7 LIMITATIONS

Although consideration will be made to ensure that the data will be valid and findings are reliable, nevertheless there could be some errors. These are due to the following factors:

- Small businesses and microenterprises in Kenya do not have structured business processes and hence collecting data on specific risk management procedures will be a challenge;
- Designing and developing a multi-agent system for risk management in small businesses will be time consuming considering the complex and dynamic nature of business risks;
- Obtaining sample data and information regarding risk from sampled businesses may be considered intrusive or interruptive and hence little or no cooperation may be provided by business owners;
- Implementing the system will be a challenge, partly because the small business owners in Kenya and risk experts may not be familiar with the use of computational devices and multiagent systems for testing purposes.

1.8 APPLICATIONS OF MULTIAGENT BASED RISK MANAGEMENT PLATFORM FOR SMALL BUSINESSES IN KENYA

Multiagent based Risk Management system may be used in several applications relating to small and medium sized enterprises in Kenya. These include the following areas:

1.8.1 Government of Kenya Social Development Funds

Probably the most important and useful application field for SME Risk Management platform is the small business and enterprises supported through the various social development funds initiated by the Government of Kenya. Through the funds, thousands of small businesses have been created. Such funds include:

- **Uwezo Fund:** The Fund was launched by His Excellency the President of the Republic of Kenya on 8th September 2013 and enacted through a Legal Notice No. 21 of the Public Finance Management Act, 2014, and published on 21st February, 2014. The Fund seeks to expand access to finances and promote women, youth and persons living with disability led enterprises at the constituency level.

According to the Government of Kenya's Ministry of Devolution and Planning, Kshs. 5,354,400,000 were allocated to the 290 counties in the republic of Kenya during the financial year 2014/2015 to support small businesses and enterprises by the target groups.

- **Youth Enterprise Development Fund:** The Fund was established in year 2006 with the sole purpose of reducing unemployment among the youth the country. The target of the fund is young people within the age bracket of 18 to 35 years and was gazetted on 8th December 2006 and then transformed into a State Corporation on 11th May 2007.

Financed over 157,000 youth enterprises to the tune of Kshs. 5.9 billion and has helped thousands of youth build their enterprises through market support and entrepreneurship training. As a result, the Fund has helped create over 300,000 jobs in the five years.

- **Women Enterprise Development Fund:** The fund was introduced in the 2007/08 Financial Year to provide support to women entrepreneurs. It had an initial budgetary allocation of Kshs. 2 billion

To ensure sustainability of small business created using such funds, the business owners can utilize the MAS Risk management platform, specially created for managing risks in small businesses to ensure losses are minimized and the businesses meet their objectives.

1.8.2 Applications for SME Credit Risk Scoring

According to FSD Kenya Report, October 2008: *The Potential for Credit Scoring for SME Lending in Kenya*, fewer than 20 percent of small to medium sized enterprises (SMEs) in Kenya have ever received credit from formal financial institutions. Access is

limited due to challenges in assessing SME risk in a cost effective manner. Lenders in Kenya address this risk-assessment problem either by not lending to SMEs at all or by requiring collateral and charging high interest rates.

Potential SME lenders will be able to use the proposed MAS Risk Management system for SMEs to assess basic trends regarding business growth, internal control and SME sustainability. This will be a key input for requiring Credit scoring and lending decisions by the financial institution or potential lenders.

1.8.3 Business Incubation Centers in Kenya

A Business Incubator is a facility designed to assist businesses to become established and profitable during their incubation period. In Kenya, there are several business incubators across the country setup to assist young Kenyans and students to nurture and start profitable business. Such Centers include:

- C4D Lab – University of Nairobi
- iHub
- iLab – Strathmore University
- Nailab
- AfriLab centre – University of Nairobi
- Chandaria Business Innovation and Incubation Centre -Kenyatta University
- KIRDI Technology Business Incubator

The MAS SME Risk Management platform will be an important tool for use by business startups and Business Incubation centers to provide assurance over the sustainability and growth of those businesses.

CHAPTER 2: LITERATURE REVIEW

2.1 OVERVIEW

Every business is subject to possible losses from unmanaged risks. An Effective risk management system should reduce the chance that a particular event will take place and, if it does take place, sound risk management should reduce its impact. Small and Medium Enterprises (SME) in Kenya do not have the skills and capacity to manage their risks internally. It is thus increasingly relevant to provide innovative tools and decision support systems that can help these small-medium enterprises (SMEs) to improve their functioning, J.B. Pérez et al (2011), A Multi-agent System for Web-Based Risk Management in Small and Medium Business). A multi-agent system (MAS) would provide a cheaper and efficient method for SMEs to identify and manage risks to their businesses.

A multi-agent system (MAS) is a system composed of multiple interacting intelligent agents. Multi-agent systems can be used to solve problems which are difficult or impossible for an individual agent or monolithic system to solve Alkhateeb & al (2010), Multi-Agent-Based System for Securing University Campus.

2.1.1 Risk and Risk Management

2.1.1.1 Definition of Risk

According to the International Standards Organization (ISO) ISO Guide 73, risk is the “effect of uncertainty on objectives”. In order to assist with the application of this definition, Guide 73 also states that an effect may be positive, negative or a deviation from the expected, and that risk is often described by an event, a change in circumstances or a consequence.

2.1.1.2 Risk Management

Risk management highlights the fact that the survival of a business entity depends heavily on its capabilities to anticipate and prepare for the change rather than waiting for the change and then react to it. The objective of risk management is not to prevent or

prohibit taking risk, but to ensure that the risks are consciously taken with complete knowledge and clear understanding so that it can be measured to help in mitigation. It is more so in the case of SMEs, R.S. Raghavan (2005).

“Risk Management” is a broad term for the business discipline that protects the assets and profits of an organization by reducing the potential for loss before it occurs, mitigating the impact of a loss if it occurs, and executing a swift recovery after a loss occurs. It involves a series of steps that include risk identification, the measurement and evaluation of exposures, exposure reduction or elimination, risk reporting, and risk transfer and/or financing for losses that may occur J.B. Pérez et al. (2012)

2.1.1.3 Risk Management Process

Risk management starts by identifying possible threats and then implements processes to minimize or negate them. According to Mihaela Ulieru and Paul Worthington (2012), Adaptive Risk Management System For Critical Infrastructure Protection), Risk management can only be effectively adopted in an organization when it has identified and understands its risks. Risk activities focus on inherent and residual risk. In an organization it is a case of competing risks, i.e. business risk, strategic risk and process risk. Risk metrics, risk drivers and a risk profile must be developed for each category of risk. Risks must then be analyzed, mitigated against and controlled all within a guiding set of priorities established according to enterprise objectives.

The International Standards Organization (ISO) 3100 defines five key steps of Risk Management process i.e. Risk Identification, Risk Assessment, Risk Mitigation Planning, Risk Mitigation Plan Implementation, and Risk Tracking. The figure below depicts the overall risk management process and the relationship between that various steps that ensure an effective Risk Management process:

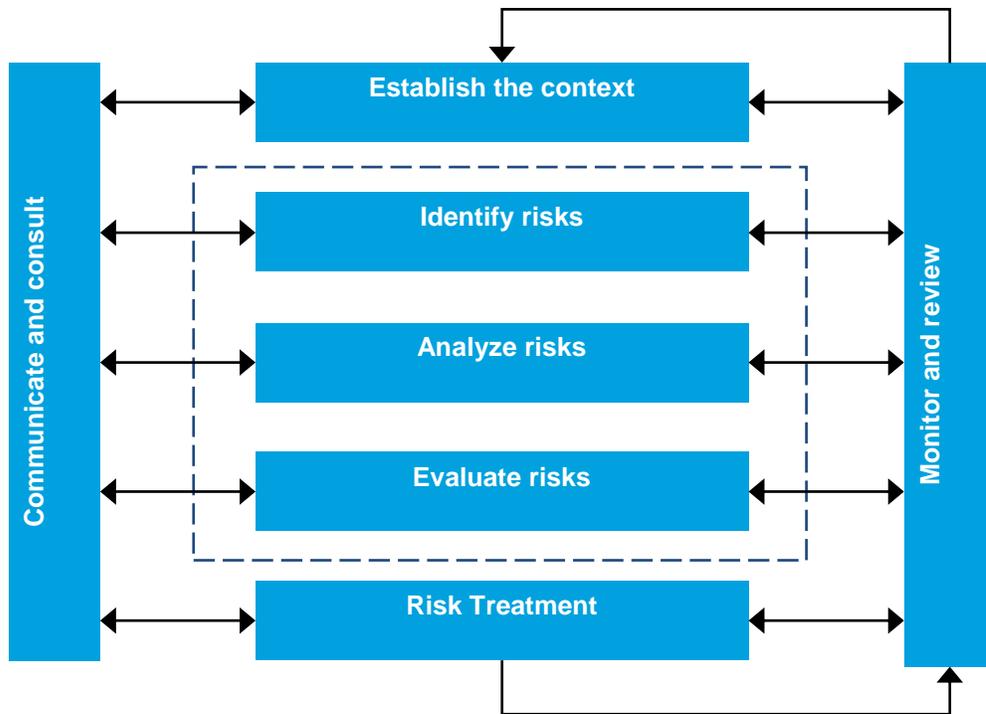


Figure 2-1: Risk management process.

Source: International Standards Organization (ISO) 31000:2011 Risk Management Principles and Guidelines

2.1.1.3.1 Establishing the Context

By establishing the context, the business articulates its objectives, defines the external and internal parameters to be taken into account when managing risk, and sets the scope and risk criteria for the remaining process. When establishing the context for the risk management process, the risk parameters are considered in greater detail and particularly how they relate to the scope of the risk management process for the business.

2.1.1.3.1.1 Establishing the external context

The external context is the external environment in which the business seeks to achieve its objectives.

Understanding the external context is important in order to ensure that the objectives and concerns of external stakeholders are considered when developing risk criteria. It is based on the business-wide context, but with specific details of legal and regulatory

requirements, stakeholder perceptions and other aspects of risks specific to the scope of the risk management process.

The external context can include, but is not limited to:

- the social and cultural, political, legal, regulatory, financial, technological, economic, natural and competitive environment, whether international, national, regional or local;
- key drivers and trends having impact on the objectives of the business; and
- relationships with, perceptions and values of external stakeholders.

2.1.1.3.2 Establishing the internal context

The internal context is the internal environment in which the business seeks to achieve its objectives.

The risk management process should be aligned with the business' culture, processes, structure and strategy. Internal context is anything within the business that can influence the way in which a business will manage risk. It is necessary to understand the internal context. This can include, but is not limited to:

- governance, business structure, roles and accountabilities;
- policies, objectives, and the strategies that are in place to achieve them;
- capabilities, understood in terms of resources and knowledge (e.g. capital, time, people, processes, systems and technologies);
- the relationships with and perceptions and values of internal stakeholders;
- the organization's culture;
- information systems, information flows and decision making processes (both formal and informal);
- standards, guidelines and models adopted by the organization; and
- form and extent of contractual relationships.

2.1.1.3.3 Establishing the context of the risk management process

The objectives, strategies, scope and parameters of the activities of the organization, or those parts of the organization where the risk management process is being applied, should be established. The management of risk should be undertaken with full consideration of the need to justify the resources used in carrying out risk management. The resources required, responsibilities and authorities, and the records to be kept should also be specified. The context of the risk management process will vary according to the needs of an organization. It can involve, but is not limited to:

- defining the goals and objectives of the risk management activities;
- defining responsibilities for and within the risk management process;
- defining the scope, as well as the depth and breadth of the risk management activities to be carried out, including specific inclusions and exclusions;
- defining the activity, process, function, project, product, service or asset in terms of time and location;
- defining the relationships between a particular project, process or activity and other projects, processes or activities of the organization;
- defining the risk assessment methodologies;
- defining the way performance and effectiveness is evaluated in the management of risk;
- identifying and specifying the decisions that have to be made; and
- identifying, scoping or framing studies needed, their extent and objectives, and the resources required for such studies.

Attention to these and other relevant factors should help ensure that the risk management approach adopted is appropriate to the circumstances, to the business and to the risks affecting the achievement of its objectives.

2.1.1.3.4 Defining risk criteria

The business should define criteria to be used to evaluate the significance of risk. The criteria should reflect the organization's values, objectives and resources. Some criteria can be imposed by, or derived from, legal and regulatory requirements and other requirements to which the business subscribes. Risk criteria should be defined at the beginning of any risk management process and be continually reviewed.

When defining risk criteria, factors to be considered should include the following:

- the nature and types of causes and consequences that can occur and how they will be measured;
- how likelihood will be defined;
- the timeframe(s) of the likelihood and/or consequence(s);
- how the level of risk is to be determined;
- the views of stakeholders;
- the level at which risk becomes acceptable or tolerable; and
- whether combinations of multiple risks should be taken into account and, if so, how and which combinations should be considered.

2.1.1.4 Risk Assessment

Risk assessment is the overall process of risk identification, risk analysis and risk evaluation.

2.1.1.4.1 Risk Identification

Risk identification establishes the exposure of the organization to risk and uncertainty. This requires an intimate knowledge of the organization, the market in which it operates, the legal, social, political and cultural environment in which it exists, as well as an understanding of strategic and operational objectives. This will include knowledge of the factors critical to success and the threats and opportunities related to the achievement of objectives.

The aim of this step is to generate a comprehensive list of risks based on those events that might create, enhance, prevent, degrade, accelerate or delay the achievement of

objectives. Comprehensive identification is critical, because a risk that is not identified at this stage will not be included in further analysis.

Identification should include risks whether or not their source is under the control of the organization, even though the risk source or cause may not be evident. Risk identification should include examination of the knock-on effects of particular consequences, including cascade and cumulative effects. It should also consider a wide range of consequences even if the risk source or cause may not be evident. As well as identifying what might happen, it is necessary to consider possible causes and scenarios that show what consequences can occur. All significant causes and consequences should be considered.

2.1.1.4.2 Risk analysis

Risk analysis involves developing an understanding of the risk. Risk analysis provides an input to risk evaluation and to decisions on whether risks need to be treated, and on the most appropriate risk treatment strategies and methods. Risk analysis can also provide an input into making decisions where choices must be made and the options involve different types and levels of risk.

Risk analysis involves consideration of the causes and sources of risk, their positive and negative consequences, and the likelihood that those consequences can occur. Factors that affect consequences and likelihood should be identified. Risk is analyzed by determining consequences and their likelihood, and other attributes of the risk. An event can have multiple consequences and can affect multiple objectives. Existing controls and their effectiveness and efficiency should also be taken into account.

Risk analysis can be undertaken with varying degrees of detail, depending on the risk, the purpose of the analysis, and the information, data and resources available. Analysis can be qualitative, semi-quantitative or quantitative, or a combination of these, depending on the circumstances. Consequences and their likelihood can be determined by modeling the outcomes of an event or set of events, or by extrapolation from experimental studies or from available data. Consequences can be expressed in terms of tangible and intangible impacts. In some cases, more than one numerical value or descriptor is required to specify consequences and their likelihood for different times, places, groups or situations.

2.1.1.4.3 Risk evaluation

The purpose of risk evaluation is to assist in making decisions, based on the outcomes of risk analysis, about which risks need treatment and the priority for treatment implementation.

Risk evaluation involves comparing the level of risk found during the analysis process with risk criteria established when the context was considered. Based on this comparison, the need for treatment is then considered. Decisions should be made in accordance with legal, regulatory and other business requirements.

The risk evaluation can also lead to a decision not to treat the risk in any way other than maintaining existing controls. This decision will be influenced by the business's risk attitude and the risk criteria that have been established.

2.1.1.4.4 Risk treatment

Risk treatment involves selecting one or more options for modifying risks, and implementing those options. Once implemented, treatments provide or modify business controls.

Risk treatment involves a cyclical process of:

- assessing a risk treatment;
- deciding whether residual risk levels are tolerable;
- if not tolerable, generating a new risk treatment; and
- assessing the effectiveness of that treatment.

Risk treatment options can include the following:

- a) **Risk Avoidance** - avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk;
- b) **Risk Acceptance** - Retaining the risk by informed decision or taking or increasing the risk in order to pursue an opportunity;
- c) **Risk Avoidance** - removing the risk source;

- d) **Risk Transfer** - sharing the risk with another party or parties (including contracts and risk financing); and
- e) **Risk Mitigation** - changing the likelihood or the consequences.

Risk treatment itself can introduce risks. A significant risk can be the failure or ineffectiveness of the risk treatment measures. Monitoring needs to be an integral part of the risk treatment plan to give assurance that the measures remain effective.

Risk treatment can also introduce secondary risks that need to be assessed, treated, monitored and reviewed.

These secondary risks should be incorporated into the same treatment plan as the original risk and not treated as a new risk. The link between the two risks should be identified and maintained.

2.1.1.4.5 Monitoring and review

Both monitoring and review should be a planned part of the risk management process and involve regular checking or surveillance. It can be periodic or ad hoc. The business's monitoring and review processes should encompass all aspects of the risk management process for the purposes of:

- ensuring that controls are effective and efficient in both design and operation;
- obtaining further information to improve risk assessment;
- analysing and learning lessons from events (including near-misses), changes, trends, successes and failures;
- detecting changes in the external and internal context, including changes to risk criteria and the risk itself which can require revision of risk treatments and priorities; and
- identifying emerging risks.

2.1.1.5 Attributes of enhanced risk management

The International Standards Organization (ISO) 31000 (2011), outlines the list of attributes below which represents a high level of performance in managing risk. To assist organizations in measuring their own performance against these criteria, some tangible indicators are given for each attribute:

a) Key outcomes

- The organization has a current, correct and comprehensive understanding of its risks.
- The organization's risks are within its risk criteria.

b) Attributes

Continual improvement: An emphasis is placed on continual improvement in risk management through the setting of organizational performance goals, measurement, review and the subsequent modification of processes, systems, resources, capability and skills. This risk management performance assessment is an integral part of the overall organization's performance assessment and measurement system for departments and individuals.

Full accountability for risks: Enhanced risk management includes comprehensive, fully defined and fully accepted accountability for risks, controls and risk treatment tasks. Designated individuals fully accept accountability, are appropriately skilled and have adequate resources to check controls, monitor risks, improve controls and communicate effectively about risks and their management to external and internal stakeholders.

Application of risk management in all decision making: All decision making within the business, whatever the level of importance and significance, involves the explicit consideration of risks and the application of risk management to some appropriate degree e.g. for decisions on the allocation of capital, on major projects and on re-structuring and organizational changes. For these reasons, soundly based risk management is seen within the organization as providing the basis for effective governance.

Continual communications: Enhanced risk management includes continual communications with external and internal stakeholders, including comprehensive and frequent reporting of risk management performance, as part of good governance. Comprehensive and frequent external and internal reporting on both significant risks and on risk management performance contributes substantially to effective governance within an organization.

2.2 SMALL AND MEDIUM ENTERPRISES (SMES)

According to the Kenya National Micro and Small Enterprise Baseline Survey, 1999, The term *micro and small enterprise* covers a range of establishments including informal sector which employ one or more persons and enterprises in the formal sector employing up to 50 persons. Whatever the site (Home Street, mobile unit) an SME may be undertaken as a main activity or as a secondary activity and may be permanent temporary casual, or seasonal. Peter Paul Kithae, et al, 2012 defines SME as an undertaking which employs between 1 and 20 employees, with capital investment of not more than Kshs 30 million. Operational and administrative management lies in the hands of one to three persons who usually make major decisions.

Small and Micro Enterprises (SMEs) play an important economic role in many countries. In Kenya, for example the SME sector contributed over 50percent of new jobs created in 2005 but despite their significance, SMEs are faced with the threat of failure with past statistics indicating that three out five fail within the first few months, Michael Bowen, et al (2009). Starting and operating a small business includes a possibility of success as well as failure. Because of their small size, a simple management mistake or failure to manage business risks is likely to lead to sure death of a small enterprise hence no opportunity to learn from its past mistakes.

2.2.1 What defines SMEs in relation to larger businesses?

Small and medium sized enterprises (SME) differ from large corporations among other aspects first of all in their size. Ann-Katrin, 2011 outlines the following differences between SMEs and larger corporations:

- **Management structure and specialty of knowledge:** In contrast to larger corporations, in SME the business owner is often part of the management team. His intuition and experience are important for managing the company. This is due to the simplified nature of SME business structure and a lack of resources in SME. As such management is mainly responsible for financial planning and risk management. However, the management often lacks the time, the information management systems and also the theoretical knowledge to go deep into the financial information of the company. The result is that many SME do not exercise a structured and standardized risk management
- **Position on Procurement Markets:** In contrast to larger companies, SMEs, due to their size are not in a dominant position on the procurement markets and can only marginally affect the conditions in contracts with their suppliers. In most cases they are dependent on them and receive worse conditions than larger companies.
- **Legal Framework:** In contrast to corporations and large companies, which are obliged by law in Kenya to install and maintain a risk management system, SME do not find legal obligations to do so.
- **Risk Management:** The risk management techniques of larger corporations cannot easily be applied to SME. Large corporations have the resources to employ a risk manager and a professional, structured and standardized risk management system. In contrast to that, risk management in SME differs in the degree of implementation and the techniques applied.

2.2.2 Risk Management Challenges Facing SMEs

Ann-Katrin (2011) states that small and medium sized enterprises, just like any other enterprise face several and often the same risks as bigger companies. In a real business environment with market imperfections they need to manage those risks in order to secure their business continuity and add additional value by avoiding or reducing transaction costs and cost of financial distress or bankruptcy

However, risk management is a challenge for most SME. In contrast to larger companies they often lack the necessary resources, with regard to manpower, databases and specialty of knowledge to perform a standardized and structured risk management. The result is that many smaller companies do not perform sufficient analysis to identify their risk. This aspect is exacerbated due to a lack in literature about methods for risk management in SME, Ann-Katrin Napp,(2011).

According to Financial Sector Deepening (FSD) Kenya's study report, SME Risk Capital Funds: Constraints to Kenyan Institutional Investors (2008), SMEs experience difficulty in securing finance because of the high level of risk and insufficient level of return associated with the industry. In addition, lack of structured and formal management of enterprise risks by SMEs makes them unattractive for funding by the financial institutions or potential investors.

In the Kenyan context, Bowen et al (2009) further outlines competition, insecurity, debt collection, lack of working capital and power interruptions as the main challenges facing small businesses. SMEs however do not formally assess these challenges from a risk perspective and ensure adequate risk management measures to ensure such challenges do not cripple or lead to the demise of their businesses.

2.2.3 SME Business Risks

The CPA Australia Business and Management Centre of Excellence (2009), Risk Management Guide for Small to Medium Businesses outlines the following key risks affecting Small and Medium Sized Enterprises:

- **Risks posed by suppliers:** If the business depends on a small number of major suppliers, production, profits and cash flow could be affected one of them fails or stops dealing with the business.
- **Risks posed by staff:** The following risks relate to SME staff:
 - If the business is seen as a short-term employer, high staff turnover could result in disruption to the business and the expense of finding and training new staff who won't deliver a return to the business if they also leave after a short time.

- If an employee is critical to the business's success, then sales and profits may suffer if the employee sets up a business in competition or goes to work for a competitor.
- If some employees are largely autonomous when dealing with key suppliers or customers, there is a risk of fraud or collusion, or there could be significant disruption to the business if they leave.
- If staff work in an unsafe environment, the business is at risk of fines and penalties and, the absenteeism, injury or even the death of an employee.
- **Risks posed by customers:** If the business relies on a small number of major customers, profit and cash flow may be affected in the short term (one to six months) if one of them stops yielding revenue.
- **Risks posed by the business premises and its location:** If the business depends significantly on its location to generate sales, a move to premises outside the immediate vicinity of the current location may disrupt the business by affecting customer, staff and supplier access. Another risk of being highly dependent on the premises is that in the event of a fire, flood or other disaster, the business may not be able to restart trading if the premises (including stock, equipment, materials and records) are destroyed. Another risk is the possibility that customers may move away from the location.
- **Risks posed by information technology:** If the business is heavily reliant on IT, the business might not be able to operate without it, for example, if a sales system fails during a high sales period.
- **Threats to goodwill and reputation:** If there is a large-scale product recall, a fraud, or other similar event, there would be a lot of bad publicity. This could cause immediate distress to the business including putting it to the trouble and expense of reworking. It would probably also cause longer term damage to the business's reputation.

- **Risks posed by financial transactions:** Financial transactions create risks for companies. They can be classified as liquidity, foreign exchange, interest rate, commodity price and credit risks. These are examined separately below:
 - **Liquidity risk:** If the business does not have enough funds, or is running out of money, there could be significant risks to the business and to the owners who might become personally responsible for the debts of the business. If liquidity is not improved, the chances getting a loan will be drastically reduced.
 - **Credit risk:** If products and services are sold on credit there is a risk that debtors will be unable to pay for them. This might result in either slow receipt of cash or even the need to write off a bad debt.
 - **Foreign exchange risk:** If the business does use and receive foreign currency in this way, then it is exposed to fluctuations in the value of foreign currency which, if not properly managed, can lead to the business making unexpected gains or losses. The size of this risk depends on the size of transactions, the number of transactions and the length of time between ordering and paying for the goods or services.
 - **Interest rate risk:** If the business is dependent on borrowed funds or income generated from savings, movements in interest rates will affect the overall profitability of the business through increases in interest expenses or reductions in income from interest.
 - **Commodity price risk:** If buying or selling commodities is a key input or output of the business, fluctuations in commodity prices can adversely affect the business's financial performance.
- **Risks posed by competitors:** Virtually every business has competitors. However, if competitors (current and potential) pose a significant threat to the business, then the viability of the business is at risk.\

- **Risks posed by the market or the economy:** If the business is at risk from changing tastes and trends, or from an economic downturn, the viability of the business is at risk.
- **Unexpected exit of the business owner:** If there is no plan to deal with the death or incapacity of the business's owner or one of the partners in a partnership, the business might have to close or be sold to a competitor to avoid putting undue pressure on the remaining owners or new owners.

2.3 BUSINESS INTELLIGENCE AND SMES

Business Intelligence has gained relevance during the last years to improve business decision making. Business Intelligence can be defined as the ability to extract actionable insight from the internal and external data available to an organization, for the purpose of supporting decision making and improving corporate performance, Mark Canes,(2009). Making effective use of Business Intelligence will be the hallmark of the well-managed SME, showing that it is an enterprise that can always answer crucial business questions, ensuring timely, accurate, information-based business decisions.

There is still a growing need of developing innovative tools that can help small to medium sized enterprises to predict risky situations and manage inefficient activities, Juan F. De Paz , et al. (2011). Small and Medium Enterprises however do not utilize business intelligence tools to safeguard growth and enhance the running of their businesses. Mark Canes (2012) outlines the following most common barriers that prevent SMEs from using business intelligence tools:

- Tight budgets;
- Lack of sophistication and organizational knowledge;
- Technology;
- Small number of employees, who are working on many projects and, therefore, have less time to spend on essential planning and analysis.

As a result, Mark Canes (2012) states that SMEs that don't adopt business intelligence will run the risk of making poor decisions, will be unaware of company inefficiencies, and will base decisions on accurate but inappropriate information. On the contrary, those enterprises that focus on the "intelligence" in business intelligence will derive positive and measurable benefits by identifying opportunities and making better decisions, based on trustworthy information. Ultimately, SMEs that implement and utilize business intelligence solutions find they can compete more effectively in the marketplace, with additional insight into customer's buying patterns and needs, and with more efficient financial management, among other benefits.

SMEs do not have deep and endless pockets like the large corporations; they cannot afford even small mistakes, The Economic Times, (2008). They need to keep innovating to remain competitive at all levels. To fuel innovation within the organization, it's necessary to have a sound enterprise intelligence strategy in place. This makes Business Intelligence a very important tool in today's continually changing market scenario. Business intelligence solutions help organizations to transform information into intelligence which in turn can fuel innovation and help organizations to leap frog their competitors.

This research presents a multiagent system especially designed to provide business intelligence to SMEs to detect risky situations and provide recommendations to business owners of SME businesses in Kenya

2.4 MULTIAGENT BASED SYSTEM FOR SME RISK MANAGEMENT

2.4.1 Definition of Agent

The term "agent" denotes a hardware or (more usually) software-based computer system that has the following characteristics:

- **Autonomy:** agents operate without the direct intervention of humans or others, and has some kind of control over its actions and internal state;
- **Social ability:** agents interact with other agents (and possibly humans) via some kind of agent-communication language;

- **Reactivity:** agents perceive their environment, (which may be the physical world, a user, a collection of other agents, the Internet, or per-haps all of these combined), and respond in a timely fashion to changes that occur in it;
- **Pro-activeness:** agents do not simply act in response to their environment; they are able to exhibit goal-directed behavior by taking the initiative.

2.4.2 Types of Agents

Passive Agents: Do not participate in a system unless specifically contacted and even then they only act within well-defined constraints.

- *Re-active Agents:* may simply be able to 'receive' a message from another agent and 'transmit' a standard response. Others may be able to process input before demonstrating behaviour dependent on the results of the process. Such behaviour may be guided by 'if-then' decision rules or some more complex decision algorithm.
- *Active Agents:* have properties that allow them to interact with other agents within the system, across system boundaries and within vertical hierarchies.
- *Adaptive agents* are capable of modifying some of their parameters or variable states or, in some instances, their rule set.

2.4.3 Components of an Agent

Efraim Turban et al. (2006), *Decision Support and Intelligent Systems*, describes the following as components of intelligent agents:

- **Owner:** User name, parent process name, or master agent name. Intelligent agents can have several owners. Humans can spawn agents, processes can spawn agents, or other intelligent agents can spawn their own supporting agents.
- **Author:** Development owner, service or master agent name. Intelligent agents can be created by people or processes and then supplied as templates for users to personalize.
- **Account:** Intelligent Agents must have an anchor to an owner's account and an

electronic address for billing purposes for billing purposes or as a pointer to their origin.

- **Goal:** Clear statements of successful agent task completion are necessary, as well as metrics for determining the task's point of completion and the value of the results. Measures of success can include simple completion of a transaction within the boundaries of the stated goal or a more complex measure.
- **Subject description:** the subject description details the goal's attributes. These attributes provide the boundaries of the agent, task, possible resources to call on, and class of need.
- **Creation and Duration:** The request and response dates requested.
- **Background:** Supporting information
- **Intelligent Subsystem:** An intelligent subsystem, such as a rule-based expert system or a neural computing system, provides several of the characteristics described above.

2.4.4 Case-Based Reasoning

Most Artificial Intelligent programs solve problems by reasoning from first principles. They can explain their reasoning by reporting the string of deductions that led from the input data to the conclusion. With human experts, however, we often observe a different type of explanation. An expert encountering a new problem is usually reminded of similar cases seen in the past, remembering the results of those cases and perhaps the reasoning behind those results. New problems are solved by analogy with old ones and the explanations are often couched in terms of prior experiences.

Computer systems that solve new problems by analogy with old ones are often called *case-based reasoning* (CBR) systems, Elaine Rich and Kevin Knight (1991). A CBR system draws its power from a large case library, rather than from a set of first principle.

2.4.5 Multiagent Systems Design

The design of a multi-agent system is an iterative process, which aims at the identification of the parties involved (i.e., human agents, system agents, external worlds),

and the processes involved, in addition to the types of knowledge needed, Frances M.T. Brazier et al. (1998). Conceptual descriptions of specific processes and knowledge are often first attained. Further explication of these conceptual design descriptions results in detailed design descriptions, most often in iteration with conceptual design. During the design of these models, partial prototype implementations may be used to analyse or verify the resulting behaviour. On the basis of examination of these partial prototypes, new designs and prototypes are generated and examined, and so on and so forth. This approach is called *evolutionary development of systems*.

Frances M.T. Brazier et al, 1998 further outlines the steps in the diagram below during a multi-agent system development process:

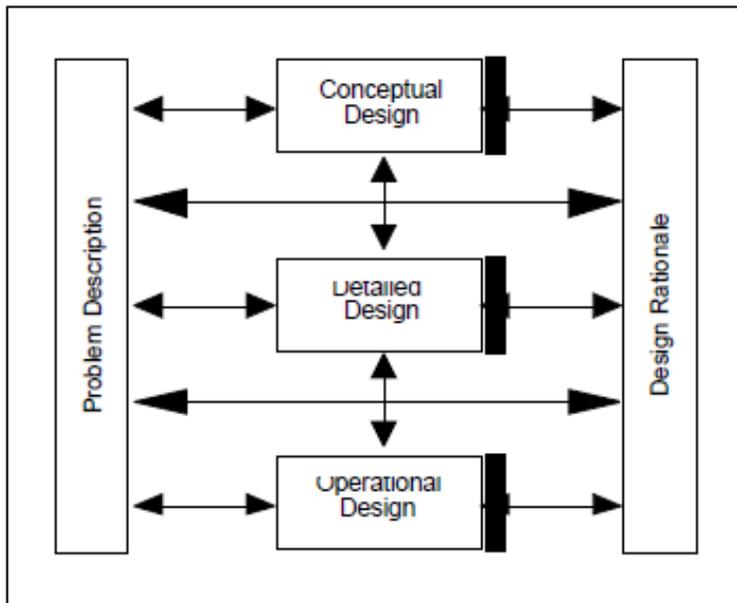


Figure 2-2: Problem description, levels of design and design rationale

Source: Frances M.T. Brazier, 1998, Principles of Compositional Multi-Agent System Development (Proceedings of the IFIP'98 Conference IT&KNOWS'98, J. Cuenca (ed.), Chapman and Hall, 1998)

The *problem description* includes the *requirements* imposed on the design: requirements often evolve during a design process. The *design rationale* specifies the choices made during design at each of the levels, and assumptions with respect to its use. The *conceptual design* includes conceptual models for individual agents, the external world

and the interaction between agents, and between agents and the external world. The *detailed design* of a system, based on the conceptual design, specifies all aspects of a system's knowledge and behavior. A detailed design is an adequate basis for *operational design*: prototype implementations can be generated automatically from the detailed design.

2.4.6 SME Risk Management System – Conceptual Design

The processes carried out inside an SME business are grouped in functional areas denominated “Functions. A Function is a group of coordinated and related activities, which are necessary to reach the objectives of the firm and are carried out in a systematic and iterative way. The functions that are usually carried out within a firm are: Purchases, Cash Management, Sales, Information Technology, Fixed Assets Management, Compliance to Legal Norms and Human Resources. In turn, each one of these functions is broken down into a series of activities.

For example, the function Purchases is divided in the following activities: Purchase Requisition, Purchase Order generation, Goods/Service Delivery, Goods Receipt and Invoicing. Each activity is composed of a number of tasks. The conceptual design below describes a system with two key components; one is the evaluation component whose objectives are: to identify the state or situation of each one of activities of the company and to calculate the risk associated with this state. The second key component is the advisor component whose goal is to generate recommendations to mitigate or reduce the impact of risks to an SME business that are brought by inconsistent processes in the business.

CHAPTER 3: METHODODOLOGY

3.1 OVERVIEW

This section discusses the methodology that was used to achieve the research objectives of the study. The chapter is organized as follows:

- Design methodology;
- Prototype development life cycle;
- Multiagent Architecture;
- System Agents, Agents conceptual model;
- Development environment;
- Source of data;
- Data collection tools;
- Data analysis methods, and
- Limitation of methodology used.

3.2 MULTI-AGENT SYSTEM METHODOLOGY

System design methods are a discipline within the software development industry which seek to provide a framework for activity and the capture, storage, transformation and dissemination of information so as to enable economic development of computer systems that are fit for purpose.

There are several MAS paradigms and methodologies that have been proposed in the literature, e.g. MASSIVE, DESIRE, Gaia and MaSE, based on different notions of agents and multi-agent organizations.

This research utilized the MaSE (Multi-agent systems Software Engineering) methodology which supports the whole development life-cycle, from problem description to realization. MaSE adopts the object-oriented paradigm (UML), by considering agents

as specialized proactive objects that coordinate by means of conversations (Gomez-Sanz J., Pavon J.: Methodologies for Developing Multi-Agent Systems). The research used a 4-stage methodology for constructing MAS for SME Risk Management: *Analysis, Design, Implementation, and Deployment* which were executed in a cyclic manner. This methodology was chosen since it allows the SME Risk Management System development to be executed in several builds, each build having only a subset of the requirements which are iteratively enhanced based on the experience (development and use) of the previous build until full functionality is attained.

3.2.1 The MaSE (Multi-agent systems Software Engineering) Methodology)

The Multiagent System Engineering (MaSE) methodology, takes an initial system specification, and produces a set of formal design documents in a graphically based style. The primary focus of MaSE is to guide a designer through the software lifecycle from a prose specification to an implemented agent system. MaSE is independent of a particular multiagent system architecture, agent architecture, programming language, or message-passing system. A system designed in MaSE could be implemented in several different ways from the same design. MaSE also offers the ability to track changes throughout the process. Every design object can be traced forward or backward through the different phases of the methodology and their corresponding constructs.

An overview of the methodology and models is shown in the figure below:

The general operation of MaSE follows the progression of steps shown in Figure 1.4 below, with outputs from one section becoming inputs for the next. The methodology is iterative across all phases with the intent that successive "passes" will add detail to the models described later. The phases are listed down the right side of the figure. The arrows indicate how the models influence each other.

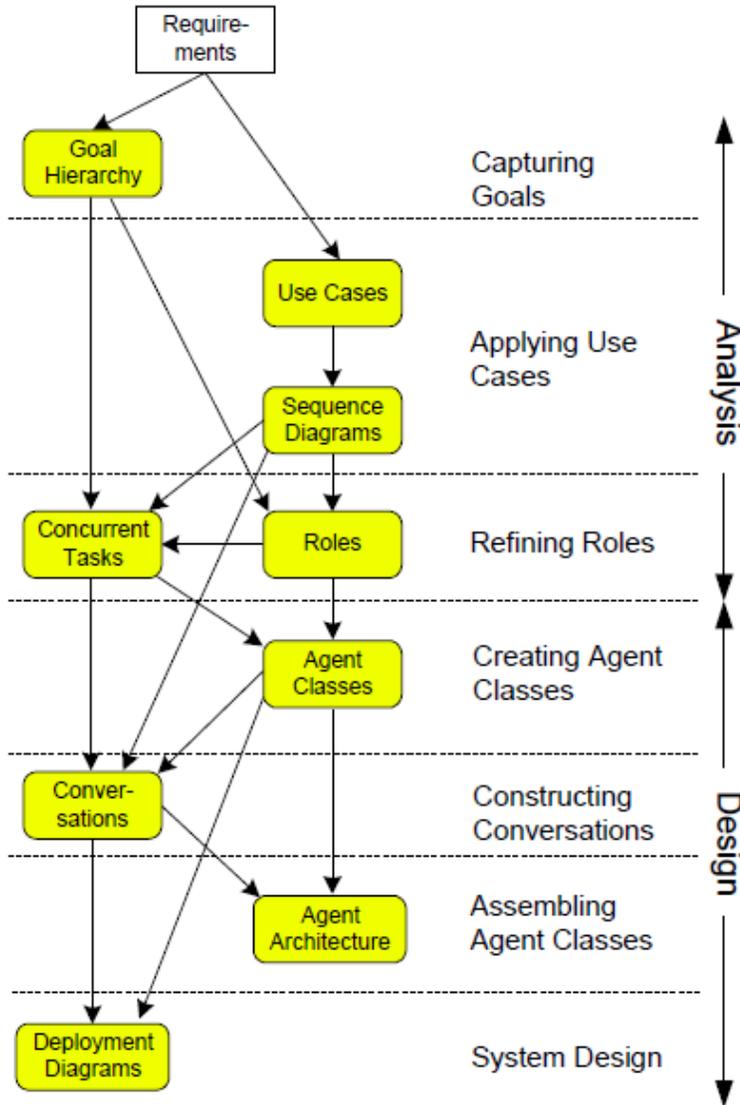


Figure 3-1: The MaSE Methodology

- Capturing Goals:** The first phase in MaSE is Capturing Goals, which takes the initial system specification and transforms it into a structured set of system goals. In the MaSE methodology, a goal is always defined as a system-level objective. Lower-level constructs may inherit or be responsible for goals, but goals always have a system-level context.

The goals are then analyzed and structured into a form that can be passed on and used in the design phases of the MaSE methodology.

- **Applying Use Cases:** It is the conversations between agents that are the real backbone of a multiagent system, as they enable the distributed operation that is the strength of agent technology. The second phase of MaSE looks down the road toward constructing these conversations and creates use cases to ease this difficulty

The Applying Use Cases phase captures use cases from the initial system requirements and restructures them as a Sequence.

- **Refining Roles:** The third step of MaSE is to transform the structured goals into a form more useful for constructing multiagent systems: roles. Roles are the building blocks used to define agent's classes and capture system goals during the design phase.

A role is an abstract description of an entity's expected function and encapsulates the system goals that it has been assigned the responsibility of fulfilling. Roles are created to do something.

- **Creating Agent Classes:** In the Creating Agent Classes phase of the MaSE methodology, the agent classes were identified from component roles. The product of this phase is an Agent Class Diagram, which depicts agent classes and the conversations between them.

During this phase of MaSE, agent classes consist of two components: roles and conversations.

- **Constructing Conversations:** A MaSE conversation defines a coordination protocol between two agents. Specifically, a conversation consists of two Communication Class Diagrams, one each for the initiator and responder. A Communication Class Diagram is a pair of finite state machines that define the conversation states of the two participant agent classes. The initiator side of a conversation is shown in Figure 1.4 below with its associated responder side shown in. The initiator begins the conversation by sending the first message.

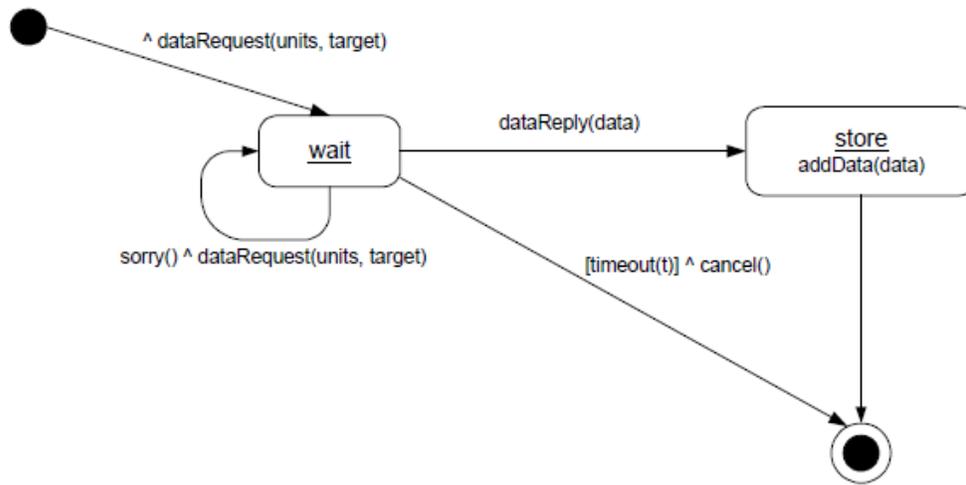


Figure 3-2: Initiator Communication Class Diagram

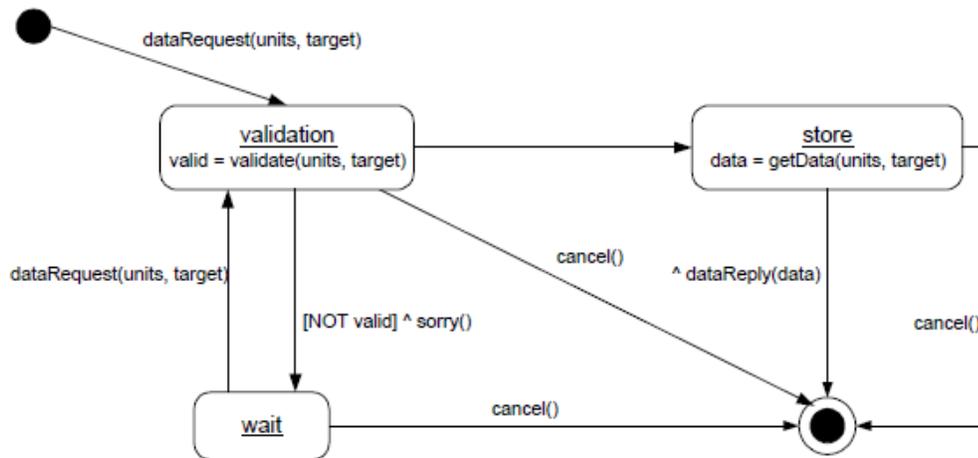


Figure 3-3: Responder Communication Class Diagram

When an agent receives a message, it compares it to its active conversations. Upon a match, the agent transitions the appropriate conversation to a new state and performs any required activities from either the transition or the new state. Otherwise, the agent compares the message to all possible conversations that it may participate in with the agent that sent the message, and begins a new conversation if the message matches a transition from the start state. Any activities in a conversation, which may occur in a state or on a transition, are mapped to methods in the corresponding agent classes.

- **Assembling Agent Classes:** In this phase of MaSE, the internals of agent classes are created. There are five different architectural style templates: Belief-Desire-Intention (BDI), reactive, planning, knowledge based, and a user-defined architecture.
- **System Design:** The final phase of the MaSE methodology takes the agent classes and instantiates them as actual agents. It uses a Deployment Diagram to show the numbers, types, and locations of agents within a system.

3.3 MULTIAGENT SYSTEM ARCHITECTURE

Logic-based (symbolic) architecture was used in representing the architecture of the system which draw its foundation from traditional knowledge-based systems techniques in which an environment is symbolically represented and manipulated using reasoning mechanisms. The advantage of this approach is that human knowledge is symbolic so encoding is easier, and they can be constructed to be computationally complete, which makes it easier for humans to understand the logic.

3.3.1 Agents Conceptual Model

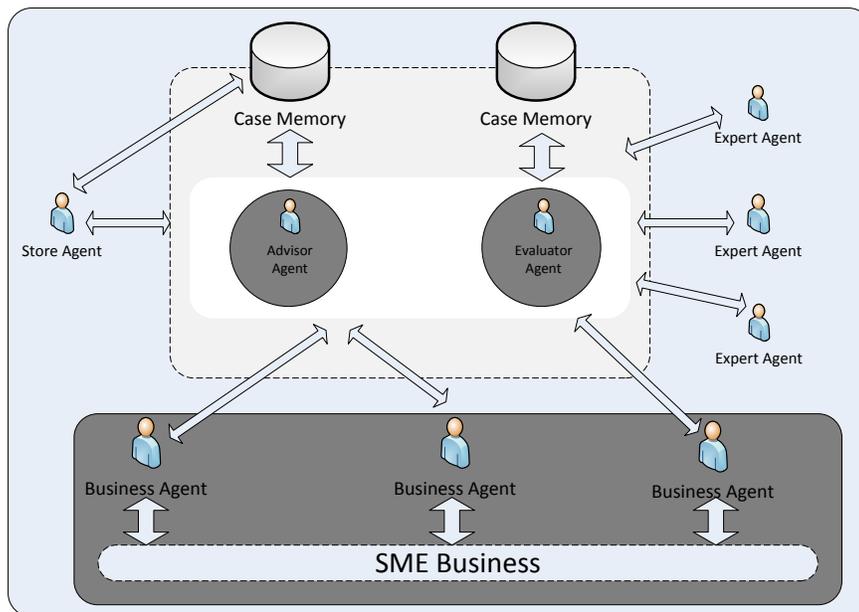


Figure 3-4: MAS Risk Management System Architecture

Source: Author's Illustration

3.3.2 System Agents

The proposed multi-agent based risk management system for SMEs adopted a simple business model that is synonymous to small and microenterprise business in Kenya. The framework has the following agents:

- **Abstract Agent class:** This is not an agent, but an abstract Java class that contains all the functionality that is common to all agents.

All agents subclass this particular class so that they can inherit the said properties without the need to write the code again for each agent.

- **Web Interface Agent:** This agent is the bridge between the user and the multi-agent system. It serves as a servlet container to the web interface via which the user (SME owner) interacts with the system.

It receives HTTP(s) requests from the user interface, decodes them to agent ontology, forwards to the appropriate agents for processing, receives the results of agent manipulations, encodes to HTTP(s) and sends back to the user.

Behaviors:

1. WebContainerHandler - runs the web interface. The web interface is realized by employing an embedded Jetty server.
2. RequestHandler - Performs routing, encoding/decoding of requests and responses to and from the user.

- **Business Agent:** This agent is assigned for each SME business function in order to collect new data and allow consultations. The business can interact with the system by means of this agent, introducing information and receiving predictions.

The business agent represents and executes the interests and actions of the business in the system. It aids in capturing data from the business, making requests on behalf of the business, and submitting results back to the business.

Behaviors:

1. ReceiveBusinessRequests - receives business routed from the Web Interface Agent. It then forwards the requests/data to the appropriate

agents, e.g. To Storage agent for data storage or Evaluation agent for risk assessment.

2. ForwardConfirmations - Sends system responses back to the Web Interface agent so that they can be submitted to the user/SME owner.

- **Evaluator Agent:** This agent is responsible for the evaluation and predictions of potential risky situations. It evaluates the given business information and tries to identify potential risks to the business.

Behaviors:

1. ReceiveRequests - Receives first time evaluation requests for new businesses
2. ReceiveSubsequentMonitoringRequests - Receives subsequent evaluation requests.
3. RiskIdentificationRequestHandler - carries out the task of analyzing business data to look for pitfalls to the business wellbeing.

- **Advisor Agent:** The objective of this agent is to carry out recommendations to help the SME business owner decide which actions to take in order to improve the company's internal and external processes. This agent receives request from business to suggest treatments or mitigating options for identified risks.

Behaviors:

1. ReceiveRequests - This is a cyclic behavior that listens for incoming Advisory requests.
2. RiskTreatmentSuggestor - One shot behavior that performs the task of making Treatment/mitigating options suggestions to the incoming requests and send responses.

- **Expert Agent:** This agent will help the SME business owner and staff to provide information and feedback to the multiagent system. The SME business owner and staff generate prototypical cases from their experience and they receive assistance in developing the Store agent case-base. It helps the business provide the relevant

information to the system so that appropriate analysis and suggestions can be carried out. This agent works closely with the business agent.

Behaviors:

1. AnalyseBusinessData - Carries out an evaluation of the information provided by a business to identify if any of it is missing
2. RequestBusinessInformation - Asks the Web Interface Agent to request for information from the business by the addition of necessary menu options that will enable the business to enter the required information.

- **Store Agent:** This agent has a memory that will be fed with cases constructed with information provided by the enterprise (through its agent) and with prototypical cases identified by the SME business owner and staff, using personal agents who have collaborated and supervised the developed model. This agent is responsible for manipulating system and business data in the database, where all other agents can access it to perform their specific roles.

Behaviors:

ReceiveAndStore - Receives and carries out data requests.

• **Agent Interaction**

The screenshot shows the 'rma@SME Risk Management Platform - JADE Remote Agent Management GUI'. The interface includes a menu bar (File, Actions, Tools, Remote Platforms, Help) and a toolbar. On the left, a tree view displays the hierarchy of agents under 'AgentPlatforms' and '"SME Risk Management Platform"'. The tree is organized into categories: Web, Persistence, Risk, and Main-Container. Each category contains several agent names, many of which are partially obscured by black redaction boxes. On the right, a table lists the details for these agents.

name	addresses	state
rma@SME Risk Management Platform		active
df@SME Risk Management Platform	http://KERISIAHO.atrema.deloitte.co...	active
ams@SME Risk Management Platform	http://KERISIAHO.atrema.deloitte.co...	active
System Runner@SME Risk Management Platform		active
Risk Platform Sniffer-on-Risk@SME Risk Management Plat...		active
Expert Agent@SME Risk Management Platform		active
Evaluator Agent@SME Risk Management Platform		active
Business Agent@SME Risk Management Platform		active
Advisor Agent@SME Risk Management Platform		active
Store Agent@SME Risk Management Platform		active
Risk Platform Sniffer-on-Persistence@SME Risk Managem...		active
Web Container Agent@SME Risk Management Platform		active
Risk Platform Sniffer@SME Risk Management Platform		active
Risk Platform Sniffer-on-Web@SME Risk Management Plat...		active

Figure 3-5: Agent Sniffer – Captures Agent Interactions and Communication

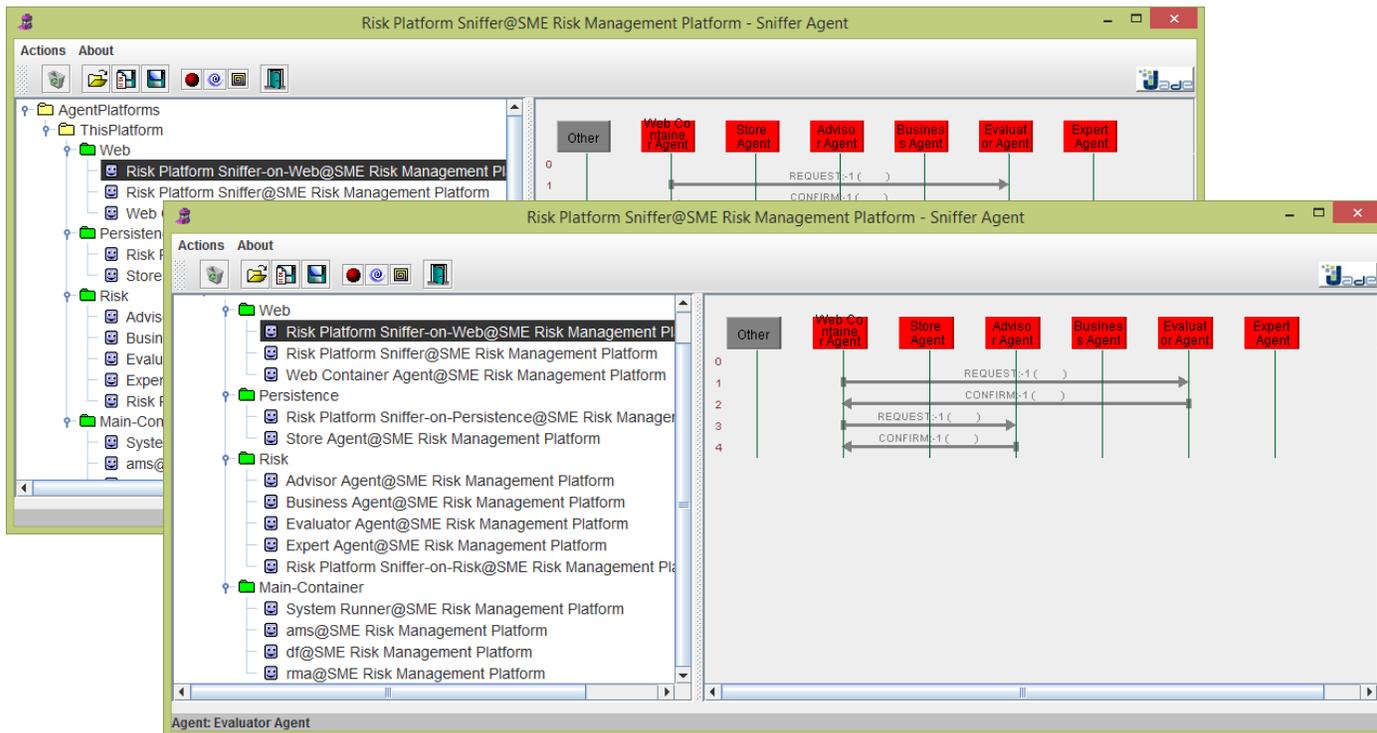
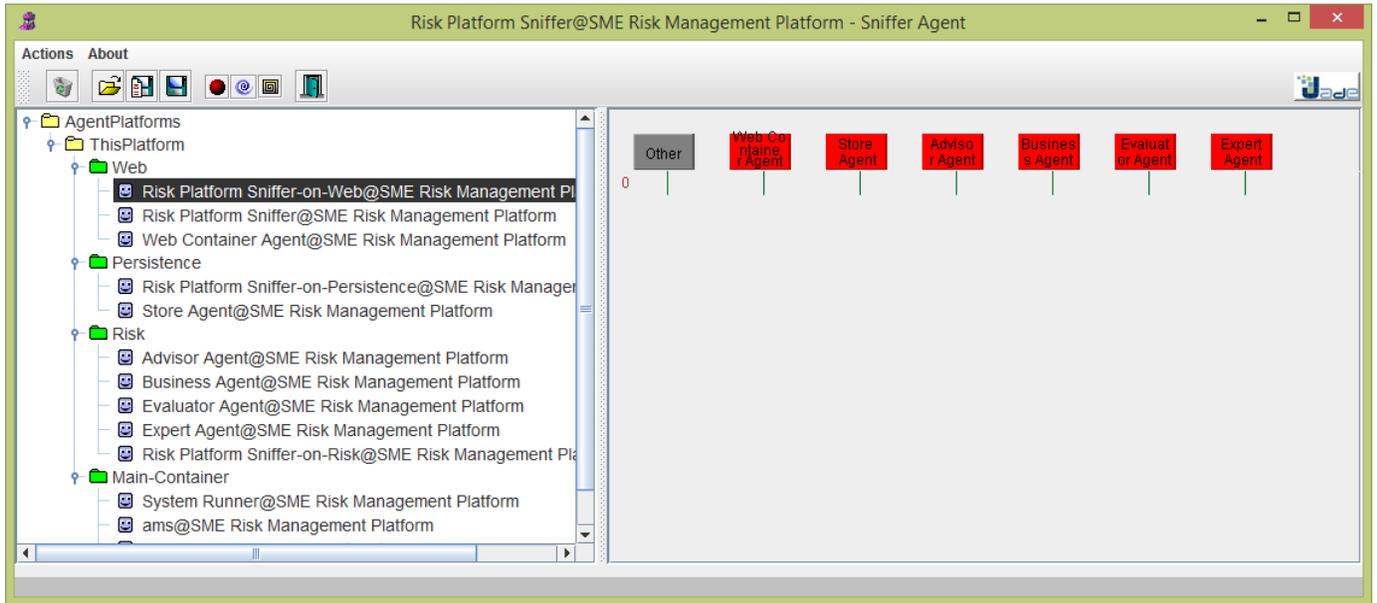


Figure 3-6: Actual Agent Interactions (Web Container Agent, Advisor Agent and Evaluator Agent)

3.3.3 Access to the System by SME owners via web interface

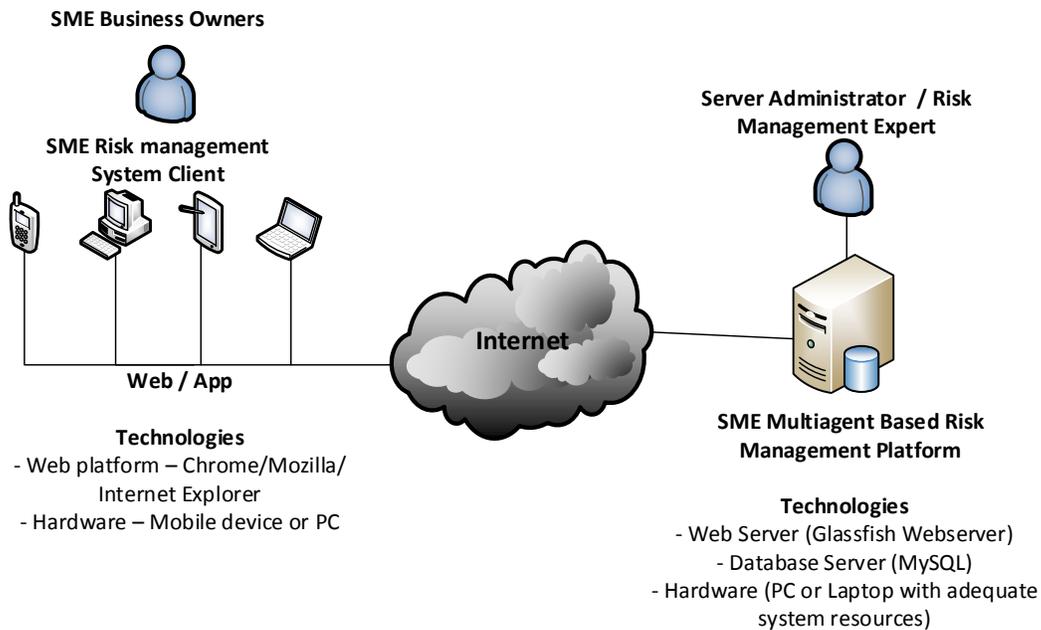


Figure 3-7: MAS Risk Management System Architecture

The Multiagent SME Risk Management System involved a distributed approach where the components of a SME were modeled as intelligent agents that collaborate to create models that can evolve over the time and adapt to the changing conditions of the environment. The multiagent system provides a web system interface to facilitate the remote interaction with the human users involved in the risk management process.

This design was intended to make it possible to detect risky situations for the SMEs and providing suggestions and recommendations that can help to avoid possible undesirable situations. The agents in the system allow the users to access the system through distributed applications, which run on different types of devices and interfaces (e.g. computers, cell phones, PDA). Figure 1.8 above shows the basic schema of the system architecture, where all requests and responses are handled by the agents in the platform.

The core of the multiagent system is the evaluator and advisor agents, that incorporate new techniques to analyze the data from the SME business processes, extract the relevant information, and detect possible failures or inefficiencies in the operation processes.

The evaluator and advisor agents are CBR-BDI agents, J.B Perez (2011), that make of past experiences to resolve new problems. As such, it is perfectly suited for solving the problem at hand. In addition, CBR (Case-Based Reasoning) makes it possible to incorporate the various stages of expression analysis into the reasoning cycle of the CBR, Kolodner (1993), thus facilitating the creation of strategies similar to the processes followed in small and medium enterprises.

3.4 DEVELOPMENT FRAMEWORK

The multiagent system was implemented using JADE (Java Agent Development Framework). JADE is a software Framework fully implemented in Java language. It simplifies the implementation of multi-agent systems through a middle-ware that complies with the Foundation for Intelligent Physical Agents (FIPA) specifications and through a set of graphical tools that supports the debugging and deployment phases. The agent platform can be distributed across machines (which do not even need to share the same Operating System) and the configuration can be controlled via a remote Graphical User Interface (GUI). Net beans an integrated development environment was be used to code java classes and agent classes then compiled in jade.

3.4.1 Requirements Specifications

Requirements specification involved designing of activities that would give the overall goals and more specific requirements for design of multiagent based risk management platform for SMEs in Kenya. The main goal of the prototype was to show how risk management in small and microenterprises can be done by agents without involving human interaction in providing ongoing risk consulting and advice to business owners. It involved the following:

Functional requirements:

- i. Ability to automate the internal control processes of an SME.
- ii. A web system interface to facilitate the remote interaction with the human users involved in the risk management process.
- iii. Ability to recover similar cases and their corresponding solutions.

- iv. Recovery of information from previous experiences to simplify the prediction process by detecting and eliminating relevant and irrelevant patterns detected in previous analyses.

Non-functional requirements

- i. Accuracy.
- ii. Speed.

The following steps were followed:

A. Requirements Gathering

Three target small business were identified in three different industries, i.e. Agriculture, Retail and Transportation. The business are located in Ongata Rongai Township of Kajiado County of Kenya.

The requirements were identified which included establishing the business context (nature of business, identifying capital requirements, Annual revenue, Expenditure, etc.), identifying long-term and short-term business objectives, understanding hindrances or challenges faced in achieving the identified business objectives and identifying and discussions required mitigating options.

The business owners were interviewed to assess the current options they have in obtaining relevant business advice regarding the challenges they face in achieving their business objectives and minimizing risks facing their businesses.

We realized that the small business owners did not first have knowledge of risks management and how and whether risks affect their businesses. We also realized that expert advice on business risk management was not available or even accessible to these small business owners. This led to identification of our agents application requirements which included: an application that can use intelligent agents in providing timely and valuable risk information to assist the small business owners in evaluating the level success of defined business objectives (revenue growth, increased profit margin, reduced losses and increased business scale) without using human interaction.

B. Analysis: environment and tasks

This is the first stage which identifies the application domain, overall problem, objectives, MAS application environment, i.e., information that will be available to an agent, actions required of the agents, and operational and performance constraints. Task decomposition was performed to determine what the system is supposed to do (and not how it is supposed to do it) to achieve overall MAS objectives for risk detection and recommendation.

C. Design: roles, interactions, and organizations

Having decomposed the problem into constituent tasks, the next stage was to identify the agents required to effectively perform the tasks in terms of (a) definition of agent roles (data, functional, decision, mediator, facilitator, etc.) linking domain-dependent application features to appropriate agent technology, and specifying services to be associated with each agent; (b) identifying the types of interactions needed between different agents in order to achieve individual or joint goals; and (c) specifying the organization of the different agents in terms of a society of agents that is consistent with the various defined roles and that achieves the overall objectives.

D. Implementation: architecture

A key requirement for implementing a MAS is the selection modes. Once certain predefined risk factors have been detected, the system updates the risk status and evaluates the corresponding risk. Based on the evaluation, the agents recommend appropriate actions to minimize the effect of the risk on the business.

3.4.2 Application data: - Research Methodology

The research used purposive interview approach to get content for the system prototype application. The content was gathered from the identified small business owners using question guided interview. The desired variables were identified and their viability established to form basis of the agents interaction and the user requirements. The prototype was developed with the necessary information on efficient and cheapest most accessible way of providing timely business intelligence to SME owners starting from risk identification to risk mitigation.

a. Data collection

This involved collecting relevant information for risk management cycle procedures relevant for a small business. This information was collected from a grocery business owner. The businesses was chosen as a representative sample of small and micro-enterprise businesses operating in Rongai Township. The data was collected using interview guided questions and also observation.

a. Data Analysis

The data collected was analysed so as to get information for the prototype which would be useful in achieving the goal of agents providing timely risk management advice to business owners. Analysis was also done for the business context, business objectives, inherent business risk and how these behave over time.

The qualitative data collected was analysed based on the following stages:

- Definition of business objectives
- Identifying inherent risks
- Applying risk mitigation options
- Monitoring achievement of business objectives
- Generating a risk profile for each cycle

The above stages formed the basis of creating agents which working together achieved the objectives of the research study.

3.4.3 Usability Evaluation

Usability evaluation was conducted to assess the implementation of the prototype. This was a user based evaluation that measured perceived business intelligence provided against achievement of business objectives. This was guided by Software Usability Measurement Inventory (SUMI) questionnaire which is an internationally-standardized questionnaire for quantitative measurement of how usable a product is, in the view of the user. It also gives a global measure of usability which includes Efficiency, Affect, Helpfulness, Control and Learn ability, which have been empirically identified as dimensions of perceived usability.

The evaluate usability questions were based on five categories which included:

Efficiency: These questions include:

The platform provides timely business advice.

- Instruction and prompts are helpful.
- I can easily access the platform when I need it.

Affect: Questions include:

- Working with this platform made me aware of the risks my business is facing.
- I have adequate knowledge on what I need to reduce impacts of risks to my business.
- The platform is presented in a way I can understand
- This software is less helpful to my business.

Helpfulness Questions includes:

- The mitigating options provided do not apply to my business context.
- The amount or quality of the risk mitigation options varies across the system.

Control: Questions includes:

- It is easy to see at a glance what the options are at each stage.
- If this software stops, it is not easy to restart it.
- It takes too long to learn the software commands.
- Learning to operate is initially full of problems.
- Sometimes I don't know what to do next with the software.

Learn ability Questions includes:

- The way that system information is presented is clear and understandable;
- I can understand and act on the information provided by this software;
- The organization of the menus or information lists seems quite logical;
- I will never learn to use all that is offered in this software.

- I have to look for assistance most times when I use this software.

3.4.4 Usability Analysis results

The prototype was deployed and installed on laptop desktop and the selected business users were invited separately to input business data. This ensured the users can access the prototype via the intranet. It was then demonstrated required business data, i.e. business context information and business objectives. They were then shown how to automatically identify risks relating to their businesses, generate a risk profile showing inherent and residual risks and were then shown how to generate graphs that indicate the progress of achievement of various business objectives based on how suggested risk mitigating options were applied. This was made to ensure all areas of system were evaluated within the time constraints.

3.5 LIMITATIONS OF METHODOLOGY

This study was only limited to the use of MASE methodology and JADE framework in demonstrating how a multiagent based risk management system can be used in providing risk management solutions to small and microenterprises in Kenya

3.6 SME RISK MANAGEMENT SYSTEM IMPLEMENTATION

We will achieve our objective by using JADE (Java Agent Development Framework) to build a multiagent system for SME Risk Management. JADE is a middleware that facilitates the development of multi-agent systems. It includes

- A **runtime environment** where JADE agents can “live” and that must be active on a given host before one or more agents can be executed on that host.
- A **library** of classes that programmers have to/can use (directly or by specializing them) to develop their agents.
- A suite of **graphical tools** that allows administrating and monitoring the activity of running agents.

The MAS for SME Risk Management will comprise the following agents:

A case study aimed at providing innovative web business intelligence for the management of SMEs in Kenya will be carried out for a sample SME business located in Nairobi, Kenya. The experiment will consist the construction of the initial prototype of memory of cases and then in predicting potential risky situations for the SME taken into consideration and providing recommendations. The case study will be oriented to detect possible risky situations in SMEs, taking into account the risks that affect SMEs in Kenya.

3.7 REVIEW

After each development iteration we compared the output product against the objectives set out and the requirements (functional and non-functional) to ascertain whether they have been met.

3.8 TESTING AND EVALUATION.

The economic context is the same for all the SMEs. The system was tested over a period of one and half months, from 1st January 2016 to 24th February 2016, tuned and improved taking into account the experience acquired using a several cases. The evolution of the SME was monitored through its internal activities and the predictions were made based on the previous experiences and on the status of the market (the possible risks that affect SMEs in Kenya). To validate the overall functioning of the system it was necessary to individually evaluate the Evaluator and Advisor agents. These agents provided predictions on the performance of the activities and detect those tasks that can be improved for each activity in order to get an overall improvement of the activity. To validate the performance of the Evaluator agent, an estimation of the efficiency of the predictions provided by the Evaluator agent was carried out.

3.9 SYSTEM DESIGN

In this phase of the development process, the description of the recommended solution, which was gotten from the analysis phase, was converted into logical specifications. This logical specification was not tied to any hardware or software; therefore they would be implemented on any hardware or software.

3.9.1 DATA FLOW DIAGRAMS

A data flow diagram (DFD) is a graphical representation of the flow of data through an information system. A DFD can also be used for the visualization of data processing during structured design. It is common practice for a designer to draw a context-level DFD first which shows the interaction between the system and outside entities. The context-level DFD is then explored further to show more detail of the system being modelled.

With a DFD, one is able to visualize how a system will operate, what the system will accomplish, and how the system will be implemented. DFDs can be used to provide the user with a physical idea of where the data they input ultimately has an effect upon the structure of the whole system. How any system is developed can be determined through a DFD.

3.9.1.1 DFD: Level 1

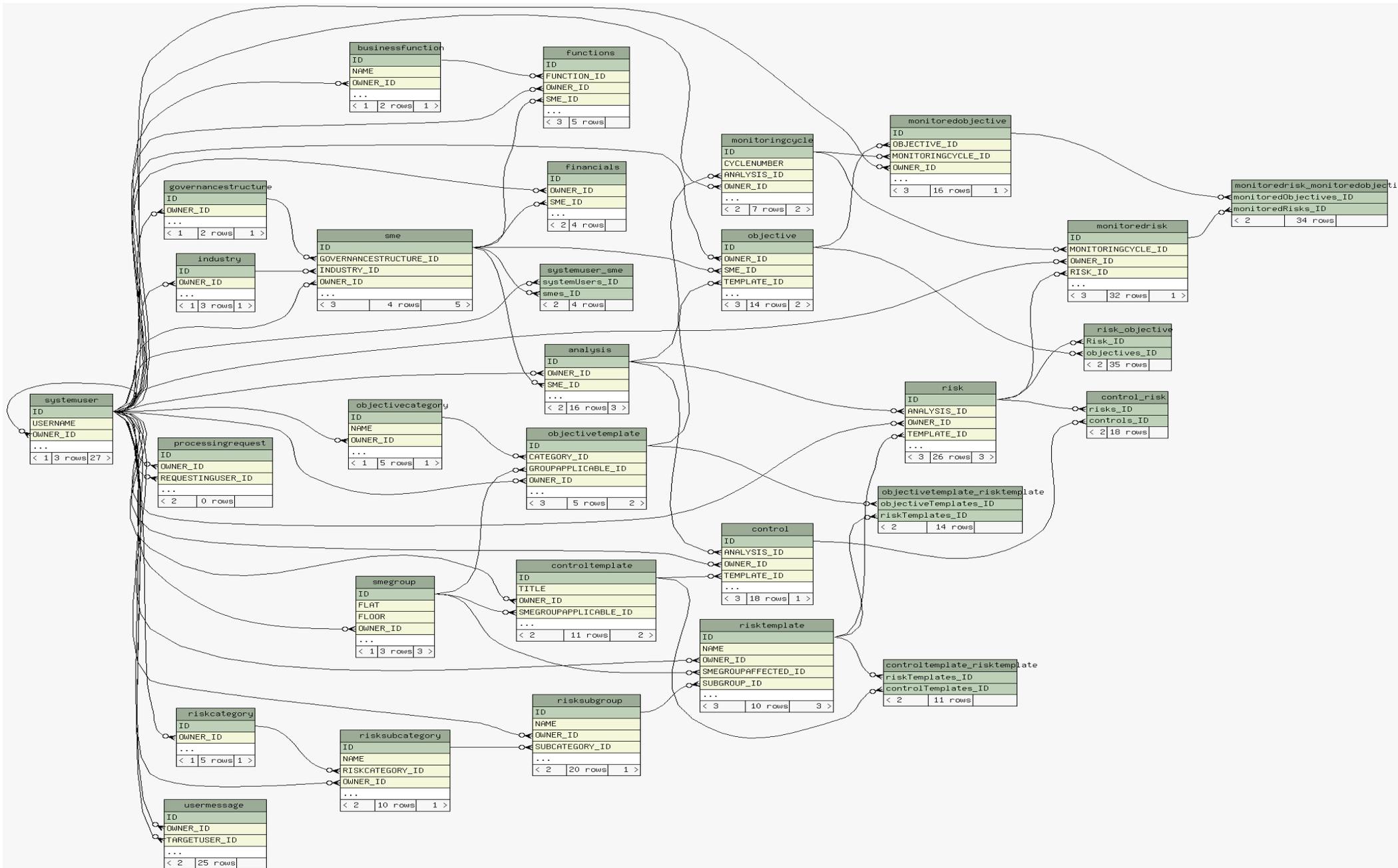


Figure 3-8: Level 1 DFD for the system

3.9.2 ALGORITHM

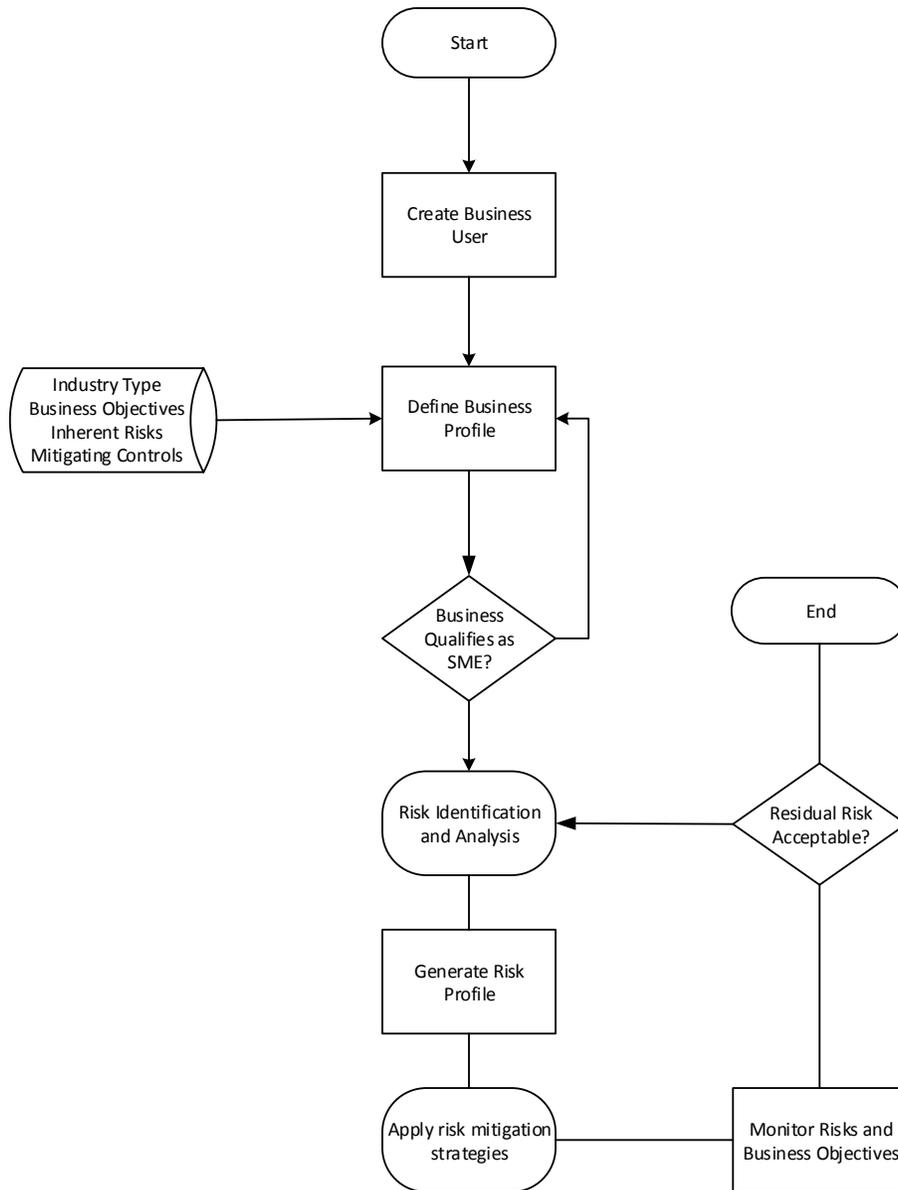


Figure 3-9: Flowchart of the algorithm used for identifying, assessing and evaluating business risks

CHAPTER 4: RESULTS AND FINDINGS

4.1 HARDWARE PLATFORM USED

The machines on which MAS Risk Management system was tested had the following specifications:

- Operating system - Microsoft Windows 8.1 Enterprise 64bit (6.3, Build 9600).
- Intel core i5-4300U quad core processor with a speed of 2.5 GHz each.
- 8192 MB RAM.

4.2 SOFTWARE PLATFORM USED

Software used in the course of this project included:

- Java™ 2 Platform, Standard Edition (J2SE™) Development Kit (JDK)
- Java NetBeans IDE 8.1 programming toolkit.
- JADE Framework libraries.
- MySQL 5.7.9 Database System
- Google chrome browser Version 47.0.2526.111 m

4.3 CHOICE OF THE PROGRAMMING LANGUAGE

Java was chosen because of its ease of learning and its versatility. The language is open-source, thus a lot of packages have been developed by other developers that can help simplify programming tasks through code re-use.

Java is also a cross-platform programming language. Its ease of programming and safety features helps one to quickly produce working code. Although the system was tested on the google chrome web browser, any web browser could be used as well.

Java is a clear and powerful object-oriented programming language, comparable to Perl, Ruby, Scheme, or python.

Some of Java's notable features:

- Uses an elegant syntax, making the programs easier to read.
- Is an easy-to-use language that makes it simple to get your program working This makes java ideal for prototype development and other ad-hoc programming tasks, without compromising maintainability.
- Comes with a large standard library that supports many common programming tasks such as connecting to web servers, searching text with regular expressions, reading and modifying files.
- Java's interactive mode makes it easy to test short snippets of code.
- Is easily extended by adding new modules implemented in a compiled language such as C or C++.
- Can also be embedded into an application to provide a programmable interface.
- Runs on many different computers and operating systems: Windows, MacOS, many brands of UNIX, OS/2 (a cross-platform programming language).
- Is free software in both senses. It doesn't cost anything to download or use java, or to include it in your application. Java can also be freely modified and re-distributed, because while the language is copyrighted it's available under an open source license.

Some programming-language features of Java are:

- A variety of basic data types are available: numbers (floating point, complex, and unlimited-length long integers), strings (both ASCII and Unicode), lists, and dictionaries.
- Java supports object-oriented programming with classes and multiple inheritance.
- Code can be grouped into modules and packages.
- The language supports raising and catching exceptions, resulting in cleaner error handling.

- Data types are strongly and dynamically typed. Mixing incompatible types (e.g. attempting to add a string and a number) causes an exception to be raised, so errors are caught sooner.
- Java contains advanced programming features such as generators and list comprehensions.

4.4 RESULTS FROM TESTING

4.4.1 SME 1: RETAIL INDUSTRY (MAMA SHARON GROCERY)

Business Context: This is a small estate grocery shop operated by the owner based in Rongai Township, Kajiado County. The business has a capital base of Ksh. 50,000 with an annual turnover of Ksh. 300,000. Average annual expenditure is Ksh. 200,000 which covers a monthly salary of 15000 for the proprietor among other day to day expenses. The owner does not employ any staff and prefers to operate the business herself.

The table below describes the identified business objectives per discussions with the proprietor and growth target.

Business Objectives		Results				
Category	Business Objective	Target Values	Actual Value (Cycle 1)	Actual Value (Cycle 2)	Actual Value (Cycle 3)	Actual Value (Cycle 4)
Margins	Realize maximum margin for sales made	100	10	25	60	65
Profit	Ensure efficient costs to maximize profit	20	5	2	20	25
Losses	Effectively manage expenses and tighten margins	30	15	40	30	35
Sustainability	Ensure growth in operations, capital and sphere	50	20	5	15	40

Table 1: SME 1 - Business objectives

The table below highlights the risks identified that would impact achievement of the business objectives for Mama Sharon’s Grocery shop. The identified risks were tracked through four cycles of one week each over a period of 1 month. Within this period, the success of achievement of intended business objectives was also measured by interviewing the SME proprietor to check the actual values, e.g. actual revenues, etc.

Business Objective	Possible (inherent) Risks	Actual Risk Levels											
		Cycle 1			Cycle 2			Cycle 3			Cycle 4		
		Likelihood/Impact/Total Risk			Likelihood/Impact/Total Risk			Likelihood/Impact/Total Risk			Likelihood/Impact/Total Risk		
Realize maximum margin for sales made	Disintermediation	9	6	54	7	4	28	5	4	20	3	2	6
	Changes in customer preferences	5	7	35	7	5	35	6	3	18	5	3	15
	Failure to maintain credit information of customers	6	4	24	3	2	6	2	3	6	2	1	2
Ensure efficient costs to maximize profit	Natural disasters	5	10	40	5	6	30	5	4	20	5	4	20
Effectively manage expenses and tighten margins	Inadequate cash flow	8	6	48	4	4	16	3	5	15	3	4	12
Ensure growth in operations, capital and sphere	Improper capital budgeting	5	2	14	5	2	10	4	2	8	4	2	8

Table 2: SME Risk Table

4.4.2 SME 2: TRANSPORT INDUSTRY (KARIUKI'S MOTOR BICYCLE TRANSPORT BUSINESS)

Business Context: This is an owner run business operating on Magadi Road, Rongai Township in Kajiado County, Kenya. The nature of the business involves ferrying passengers within Rongai Township to and from various destinations within the township. The business has a capital base of KES 150,000 being the cost of the motor cycle. The annual turnover for the business is approximately KES 350,000 and an estimated annual expenditure of approximately KES 240,000, mainly being proprietor's 'salary', rent and meals.

The table below describes the identified business objectives per discussions with the proprietor and growth target.

Business Objectives		Results				
Category	Business Objective	Target Values	Actual Value (Cycle 1)	Actual Value (Cycle 2)	Actual Value (Cycle 3)	Actual Value (Cycle 4)

Margins	Realize maximum margin for sales made	40	5	15	50	75
Profit	Ensure efficient costs to maximize profit	40	20	20	30	37
Losses	Effectively manage expenses and tighten margins	40	30	5	20	35
Sustainability	Ensure growth in operations, capital and sphere	45	10	15	30	40

Table 3: SME 2 - Business Objectives

The table below highlights the risks identified that would impact achievement of the business objectives for Kariuki's Motor Bicycle Transport Business. The identified risks were tracked through four cycles of one week each over a period of 1 month. Within this period, the success of achievement of intended business objectives was also measured by interviewing the SME proprietor to check the actual values, e.g. actual revenues, etc.

Business Objective	Possible (inherent) Risks	Actual Risk Levels											
		Cycle 1			Cycle 2			Cycle 3			Cycle 4		
		Likelihood/Impact/Total Risk											
Realize maximum margin for sales made	Disintermediation	8	3	24	4	4	16	3	4	12	1	2	2
	Changes in customer preferences	6	6	36	5	6	30	8	3	24	4	3	12
	Failure to maintain credit information of customers	5	4	20	4	2	8	1	2	2	2	1	2
Ensure efficient costs to maximize profit	Natural disasters	4	10	40	4	7	28	3	4	12	3	3	9
Effectively manage expenses and tighten margins	Inadequate cash flow	6	5	30	4	5	20	4	4	16	3	3	9
Ensure growth in operations, capital and sphere	Improper capital budgeting	3	3	9	3	2	6	3	3	9	4	4	16

Table 4: SME 2: Risk Table

4.4.3 SME 3: MANUFACTURING INDUSTRY (EVA’S TAILOR SHOP)

Business Context: Eva’s Tailor shop is located in Rongai Township in Kajiado County, Kenya. The nature of the business involves making clothes of all sizes for men, women and children. Other services involve clothe repair works. The business’ clientele mainly reside in Rongai Township. Eva’s Tailor Shop employs three staff, including the proprietor. The capital base is estimated at KES 450,000 mainly made up of equipment and furniture costs. Annual turnover is approximately KES 750,000 while expenses are estimated at KES 500,000 which are mainly salaries, rest and inventory costs.

The table below describes the identified business objectives per discussions with the proprietor and the respective growth targets.

Business Objectives		Results				
Category	Business Objective	Target Values	Actual Value (Cycle 1)	Actual Value (Cycle 2)	Actual Value (Cycle 3)	Actual Value (Cycle 4)
Margins	Realize maximum margin for sales made	70	15	20	45	85
Profit	Ensure efficient costs to maximize profit	70	0	10	30	45
Losses	Effectively manage expenses and tighten margins	70	5	45	35	90
Sustainability	Ensure growth in operations, capital and sphere	70	2	0	15	50

Table 5: SME 3: Business Objectives

The table below highlights the risks identified that would impact achievement of the business objectives for Eva’s tailor Shop. The identified risks were tracked through four cycles of one week each over a period of 1 month. Within this period, the success of achievement of intended business objectives was also measured by interviewing the SME proprietor to check the actual values, e.g. actual revenues, etc.

Business Objective	Possible (inherent) Risks	Actual Risk Levels			
		Cycle 1	Cycle 2	Cycle 3	Cycle 4
		Likelihood/Impact/Total Risk	Likelihood/Impact/Total Risk	Likelihood/Impact/Total Risk	Likelihood/Impact/Total Risk

Realize maximum margin for sales made	Disintermediation	5	6	30	5	4	20	4	2	8	4	3	12
	Changes in customer preferences	6	7	42	6	5	30	5	5	25	3	4	12
	Failure to maintain credit information of customers	5	7	35	5	5	25	5	3	15	4	2	8
Ensure efficient costs to maximize profit	Natural disasters	5	10	50	5	6	30	4	6	24	5	4	20
Effectively manage expenses and tighten margins	Inadequate cash flow	9	6	56	6	4	24	6	5	30	4	2	8
Ensure growth in operations, capital and sphere	Improper capital budgeting	5	3	15	4	2	8	4	1	4	3	2	6

Table 6: SME 3: Risk Table

4.4.4 SME 4: HOSPITALITY INDUSTRY (RONGAI FISH AND CHIPS CAFÉ)

Business Context: Rongai Fish and Chips Café is located in Rongai Township, at the main bus terminus in Kajiado County, Kenya. The nature of the business involves making and selling food to passengers and town residents. The business employs four staff and is owner managed. The capital base is estimated at KES 400,000 mainly made up of equipment and furniture costs. Annual turnover is approximately KES 800,000 while expenses are estimated at KES 650,000 which are mainly salaries and rent.

The table below describes the identified business objectives per discussions with the proprietor and the respective growth targets.

Business Objectives		Results				
Category	Business Objective	Target Values	Actual Value (Cycle 1)	Actual Value (Cycle 2)	Actual Value (Cycle 3)	Actual Value (Cycle 4)
Margins	Realize maximum margin for sales made	50	25	20	55	80
Profit	Ensure efficient costs to maximize profit	50	0	10	5	15
Losses	Effectively manage expenses and tighten margins	50	25	30	50	70
Sustainability	Ensure growth in operations, capital and sphere	50	0	5	5	15

Table 7: SME 4 - Business Objectives

The table below highlights the risks identified that would impact achievement of the business objectives for Rongai Fish and Chips Café. The identified risks were tracked through four cycles of one week each over a period of 1 month. Within this period, the success of achievement of intended business objectives was also measured by interviewing the SME proprietor to check the actual values, e.g. actual revenues, etc.

Business Objective	Possible (inherent) Risks	Actual Risk Levels											
		Cycle 1			Cycle 2			Cycle 3			Cycle 4		
		Likelihood	Impact	Total Risk	Likelihood	Impact	Total Risk	Likelihood	Impact	Total Risk	Likelihood	Impact	Total Risk
Realize maximum margin for sales made	Disintermediation	5	7	35	6	4	24	6	2	12	3	1	3
	Changes in customer preferences	6	6	36	5	5	25	4	3	12	5	2	10
	Failure to maintain credit information of customers	7	6	42	4	2	8	1	3	3	1	4	4
Ensure efficient costs to maximize profit	Natural disasters	3	10	30	3	6	24	3	2	6	3	1	3
Effectively manage expenses and tighten margins	Inadequate cash flow	7	7	49	5	6	30	3	4	4	3	2	6
Ensure growth in operations, capital and sphere	Improper capital budgeting	5	4	20	3	3	9	3	1	3	2	2	4

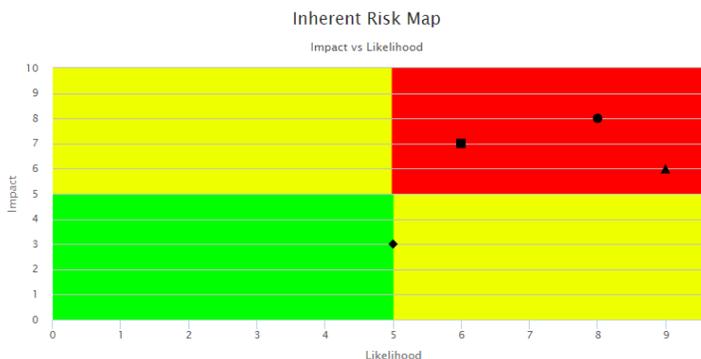
Table 8: SME 4: Risk Table

4.4.5 RISK ANALYSIS

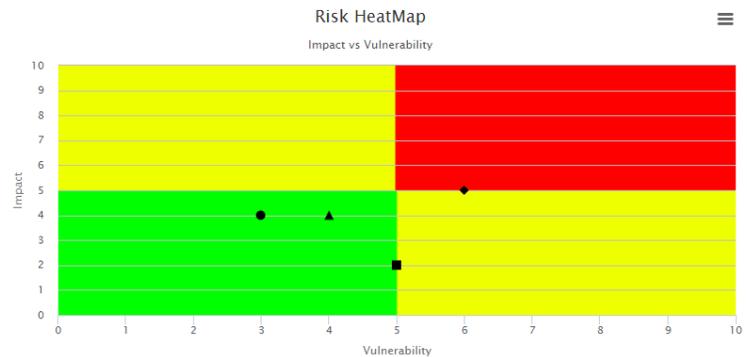
The following figures show the risk profile SME 1 over time.

a) SME 1: Retail Industry (Mama Sharon’s Grocery)

Risk Profile (Cycle 1)

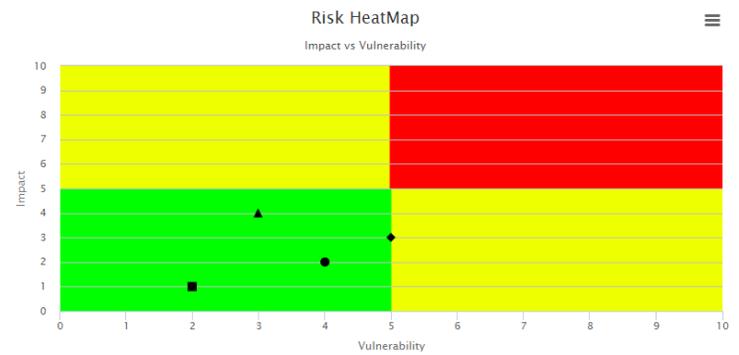
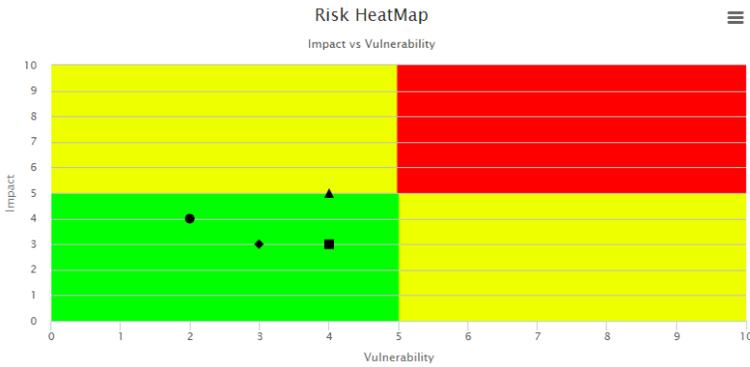


Risk Profile (Cycle 2)



Risk Profile (Cycle 3)

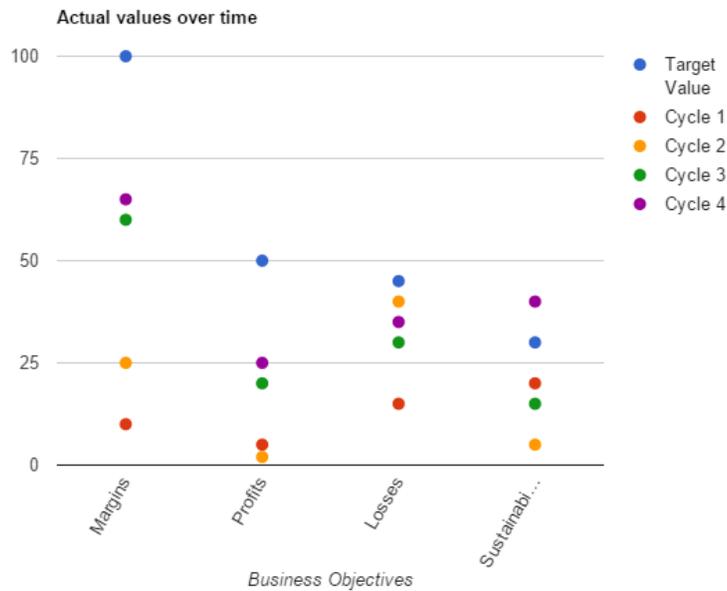
Risk Profile (Residual Risk - Cycle 4)



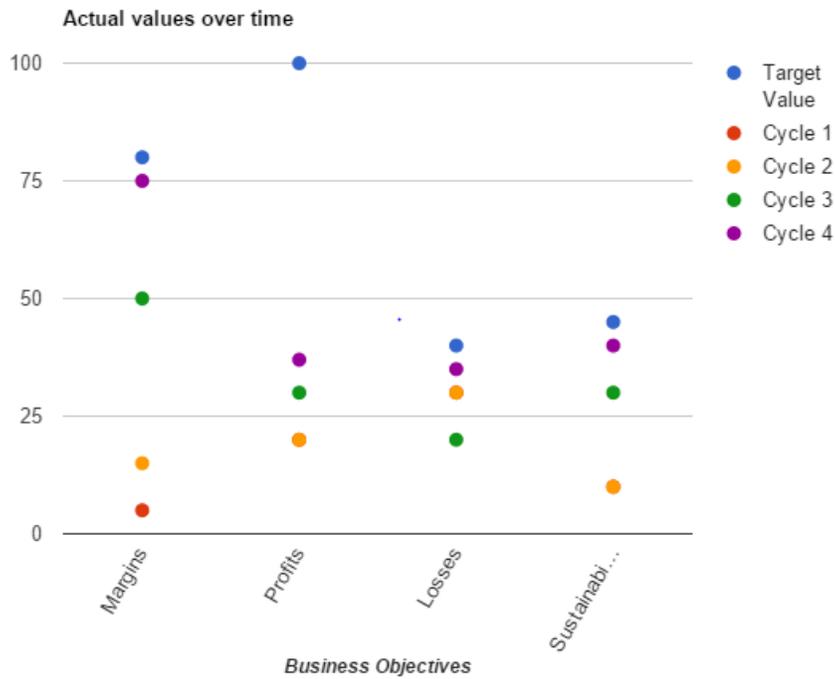
4.4.6 STATUS OF BUSINESS OBJECTIVES OVER TIME

The figures below show a graphical representation of the status of achievement of business objectives for each business tested:

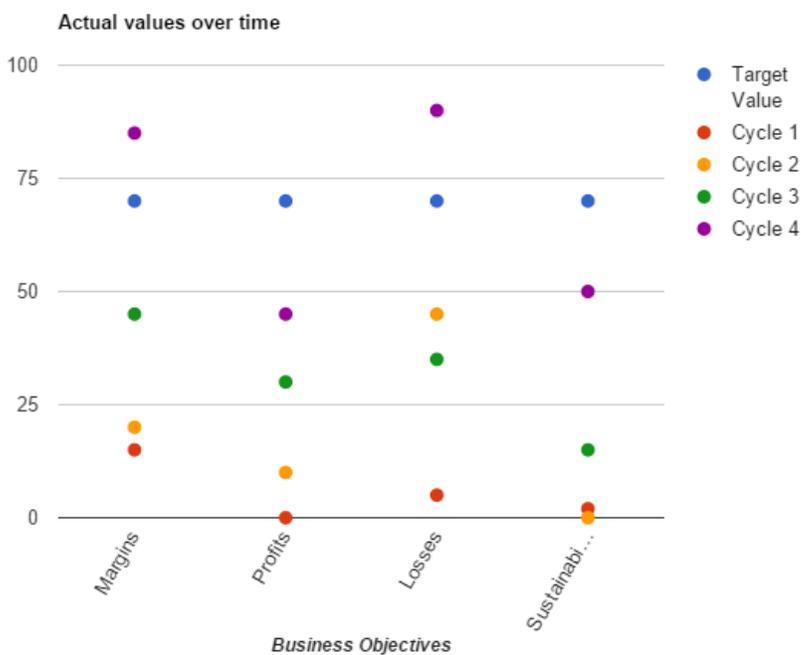
a) SME 1: Retail Industry (Mama Sharon’s Grocery Shop)



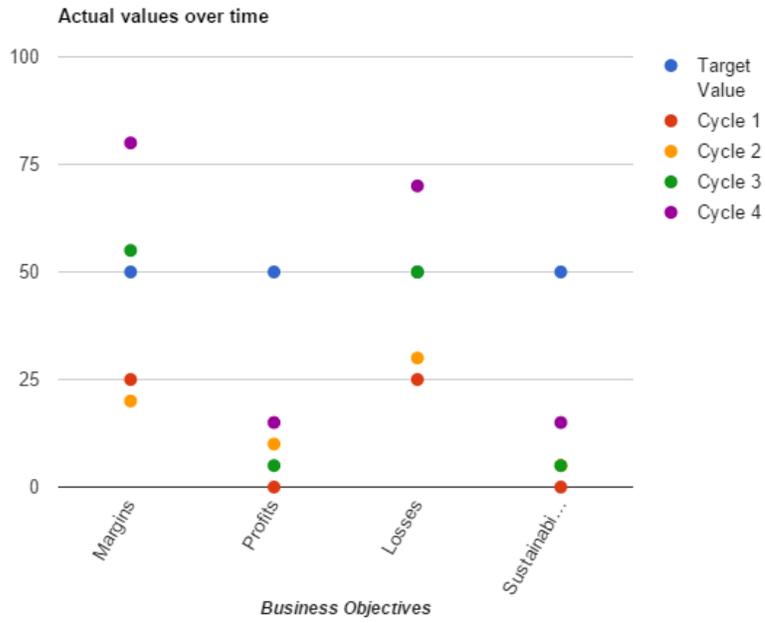
b) SME 2: Transport Industry (Kariuki Motor Cycle Transport Business)



c) SME 3: Manufacturing Industry (Eva's Tailor Shop)



d) SME 4: Hospitality Industry (Rongai Fish and Chips Café)



CHAPTER 5: DISCUSSION

5.1 CONCLUSION

Despite the fact that Small and Micro-enterprises in Kenya provide employment and a source of living to the majority of the country's population, they do not have access to readily available expert advice in risk management to ensure survival of such business. As a result, many Kenyans invest their money to start business with no assurance of whether such business will survive or make profit at all.

The use of a Multiagent Risk Management platform, specifically designed for SMEs provides an easy and cheap way of access expert advice on business risk management and continuously monitor their businesses on a continuous basis. A multiagent system for risk management is better than other systems because the agents can be modelled to dynamically interact with the business owner and learn various aspects on the SME.

In conclusion objectives of the project were achieved because so far the MAS SME Risk Management Platform is able to;

- “Interview” the SME business owner to understand the business context.
- Generate a risk profile for each business created in the system.
- Assist the SME business owner to continuously monitor various business objectives against existing risks.
- Suggest mitigating options to the business risks identified which may impact the success and even survival of the business.
- Monitor actual achievement of business objectives in line with the existing risk conditions facing the business.

Furthermore, the MAS Risk Management platform can be very useful especially for potential investors and lending institutions who may wish to know the current risk profile of an SME prior to injecting capital or extending a loan facility.

5.2 ACHIEVEMENTS

As a result of this study, a multiagent based Risk Management platform was created, designed to assist small and microenterprises in Kenya to effectively manage business risks. This MAS Risk Management system can easily be modified to adopt to any type and size of business. The system's availability on a web interface makes it easily available and flexible for use by any business owner on Kenya. This kind of flexibility makes the MAS SME Risk Management Platform to be better than most risk management applications in the market.

This project also enabled the author of this document to learn a lot of issues related to agent development and programming. The author learnt the JADE Framework for multiagent system development and did a lot of research pertaining to software development in order to be able to create the MAS Risk Management Platform.

The objectives of the project were realised with the following deliverables being achieved;

- Basic business objectives needed to ensure success of small businesses in Kenya
- Inherent risks that face small and microenterprises in Kenya
- MAS Risk Management System
- Documentation.

5.3 CONSTRAINTS

There are several notable constraints that were encountered in the course of this project. They are outlined below:

- Finding small business owners that could trust us with their business information was difficult. As a result, testing could not be done over a wide range of businesses.

- It was difficult for business owners to spare adequate time in order to provide information needed. This could only be done either after business hours or when there were no customers to be served.
- There was limited guarantee the SME owner would be available at the time of the subsequent cycle of review.

5.4 SUGGESTIONS FOR FURTHER WORK

- The MAS SME Risk Management Platform can be modified to work on mobile platforms running on smart phones. Given the growing access to smart phones in Kenya, SME owners will be able to access the platform via their mobile phones through either google play store or apple appstore.
- Further research can also be done to enable the system have other features added to cover related activities for SMEs. These include operational management systems, financial (general ledger) management systems. For example, as opposed to the user inputting financial data and other data relating to profitability, sales and margins, the MAS SME Risk Management Platform can automatically reference this data from the respective systems through an automated interface to those systems.

CHAPTER 6: REFERENCES

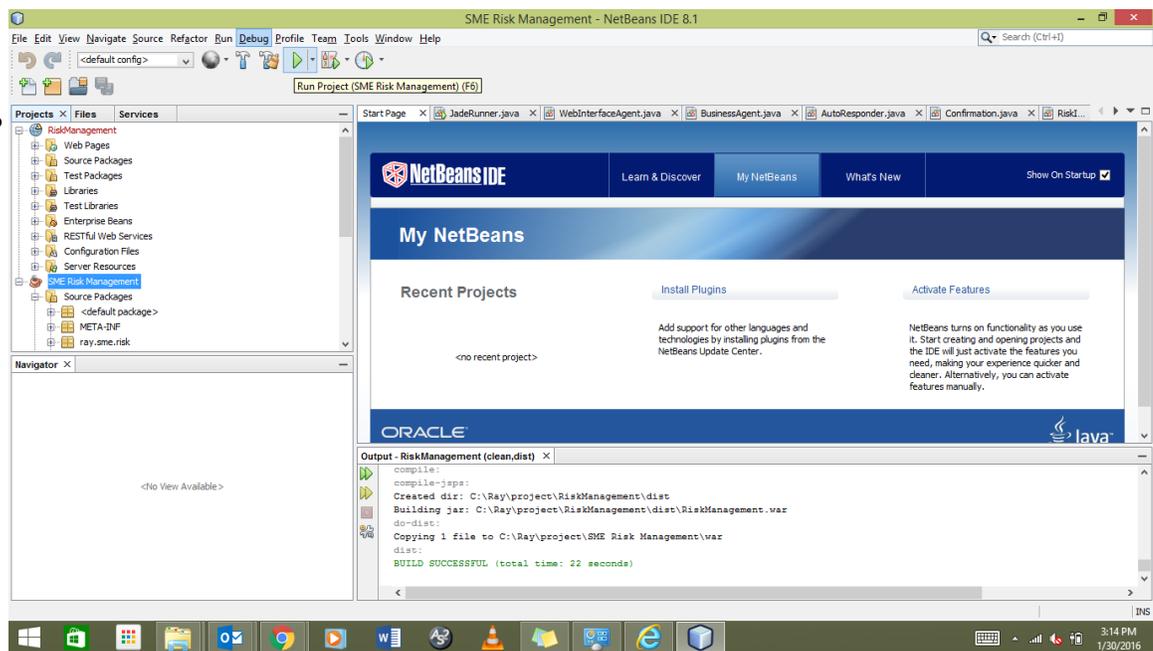
1. Mark F. Wood and Scott A. DeLoach: An Overview of the Multiagent Systems Engineering Methodology
2. Development. Proceedings of the IFIP'98 Conference (1998).
3. Juan F. De Paz et al (2011), A Multiagent System for Web-Based Risk Management in Small and Medium Business.
4. Juan M. Corchado et al (2011), Autonomous Internal Control System for Small to Medium Firms
5. Ann-Katrin Napp (2011) Financial Risk Management in SME, Master Thesis, Aarhus School of Business, Aarhus University.
6. Central Bureau of Statistics (1999), National Micro and Small Enterprise Baseline Survey.
7. Central Bureau of Statistics (2010, 2011 and 2012), Economic Survey.
8. Elaine Rich & Kevin Knight (1991), Artificial Intelligence , McGraw-Hill, 2nd edition
9. Fabio Bellifemine, et al (2004) Developing Multi-Agent Systems with JADE,
10. Financial Sector Deepening (FSD) Trust, Kenya (2008), SME Risk Capital Funds, Constraints to Kenyan Institutional Investors
11. Frances M.T. Brazier, et al (1998), Principles of Compositional Multi-Agent System Development.
12. Gomez-Sanz J and Pavon J (2004), Methodologies for Developing Multi-Agent Systems,
13. Mark F. Wood and Scott A. DeLoach (2001), An Overview of the Multiagent Systems Engineering Methodology.
14. Mark Canes (2009), Business Intelligence for the SME
15. Michael Bowen et al (2009), Management of Business Challenges among Small and Micro Enterprises In Nairobi-Kenya.
16. Peter Paul Kithae, et al (2012), The Place of Micro and Small Enterprises in Achievement of Kenya's Vision 2030.
17. The National Economic and Social Council of Kenya (2007), Kenya Vision 2030 Strategy,
18. Yolande Smit (2012), A Structured Approach To Risk Management For South African SMEs.

APPENDIX B: USER MANUAL

MAS RISK MANAGEMENT PLATFORM FOR SMEs

Systems Setup

- Start the MAS SME Risk Management Server by launching the NetBeans project and running the project per screen below:

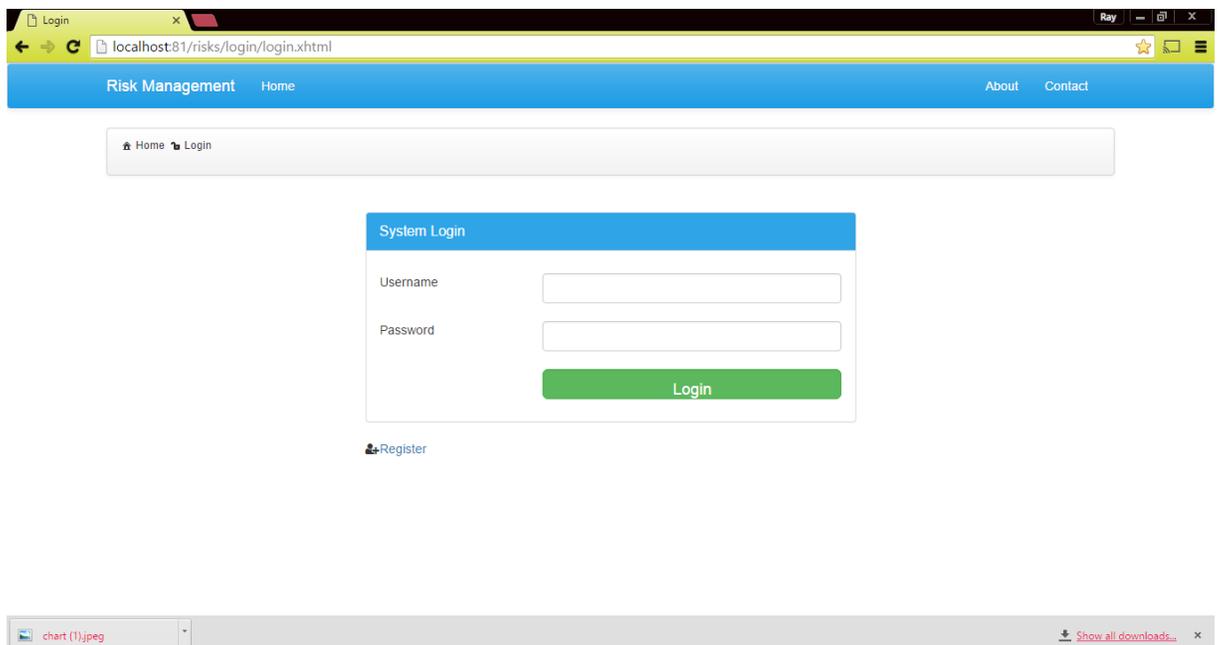


- Copy the following files from the CD provided onto a suitable folder in your computer:
 - Lib
 - Logs
 - War
 - APDescription.txt
 - MTPs-Main-Container.txt
 - Run.bat

- SME_Risk_Management.jar
- Run the system by executing the SME_Risk_Management.jar file
- Follow the instructions in the setup wizard, selecting among others, the location to store the program's files. After each screen, click on the next button to proceed, until you finish.

Using the MAS SME Risk Management Platform

1. Using your preferred web browser, type the server address. In this case, http://localhost:81/risks/login/login.xhtml
2. The MAS SME Risk Management Platform GUI has an interface that is similar to that web applications. Therefore, using the various controls should be quite easy and natural. The GUI has an interface shown below:



3. The MAS SME Risk Management platform has an administrator control panel and a user panel. Enter your administrator user name and password in the login interface to perform required administrative activities. These may include creating and removing users, amending page templates, among others. The user panel allows owners of small and micro-enterprises to register and manage their

business within the platform. Once you have entered the required login details, click the using the **‘login’** menu in order to gain access into the platform.

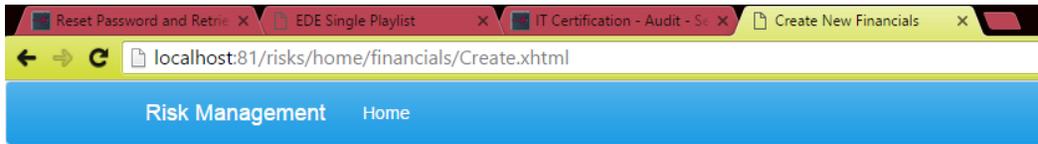
4. Create a business profile by following the instructions on the page
5. Generate a risk profile – Inherent Risk
6. Generate the Monitoring Graph for each review cycle.
7. The graphics below show the various aspects of the system to guide the user.

Step 1: Creating a business and polulating required context

The image displays two screenshots of a web application interface for SME management. Both screenshots show a browser window with the URL `localhost:81/risks/home/Edit.xhtml` and a blue header bar with "Risk Management" and "Home" links.

Left Screenshot: Shows a form for creating a business profile. The form includes fields for "Id: *", "Name: *", "Industry:", "Address:", "Description:", and "GovernanceStructure:". A dropdown menu is open under "Manage SME", showing options: "Add Financials", "Create Objectives", "Create Functions", and "Manage Rongai Grocery Shop". The "Address" field contains "1234 Rongai" and the "Description" field contains "Owner managed business". The "GovernanceStructure" dropdown is set to "Sole Proprietorship". Below the form are links for "View SME", "Show All SME Items", and "Home".

Right Screenshot: Shows the same form with data entered. The "Id" field contains "9", the "Name" field contains "Mama Sharon Kiosk", the "Industry" dropdown is set to "Retail Industry", the "Address" field contains "Rongai Township", and the "Description" field contains "Estate Kiosk based in Rongai". The "GovernanceStructure" dropdown is set to "Sole Proprietorship". Below the form are links for "View SME", "Show All SME Items", and "Home".



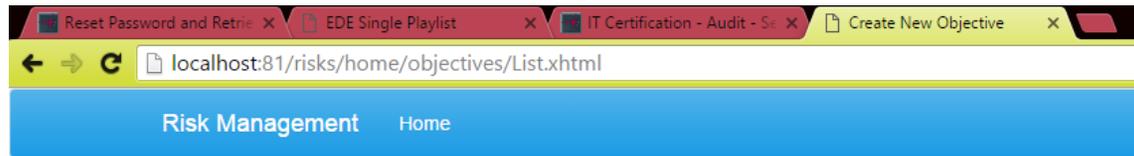
Home SME's Logout

Capital: 30000
TurnOver: 60000
Expenses: 20000
Sme: Rongai Grocery Shop

Save

Home

Step 2: Selecting relevant Business Objectives



Home SME's Logout

Template: ---

Sme: ---

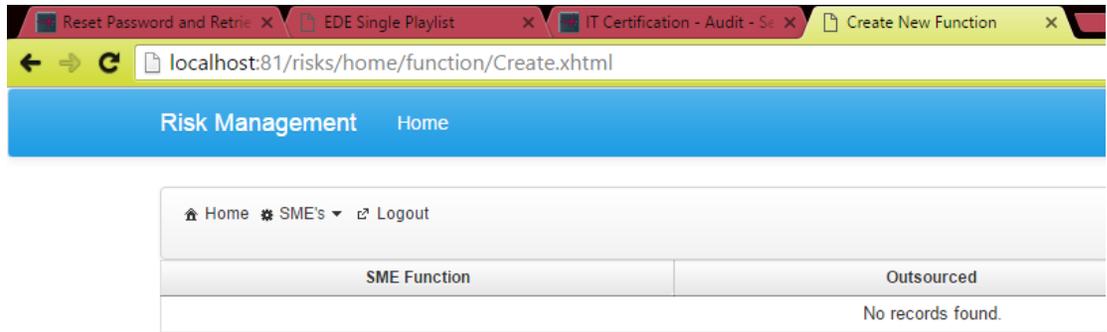
Value

Save

- Realize maximum margin for sales made[Grow Margins]
- Ensure efficient costs to maximize profit[Grow Profit]
- Effectively manage expenses and tighten margins[Reduce Losses]
- Ensure growth in operations, capital and sphere[Grow Scale]
- Implement measures to ensure continual survival of the business s[Enhance Sustainability]

SME Objectives

Index



Step 3: Risk Identification

Add Function

Function:

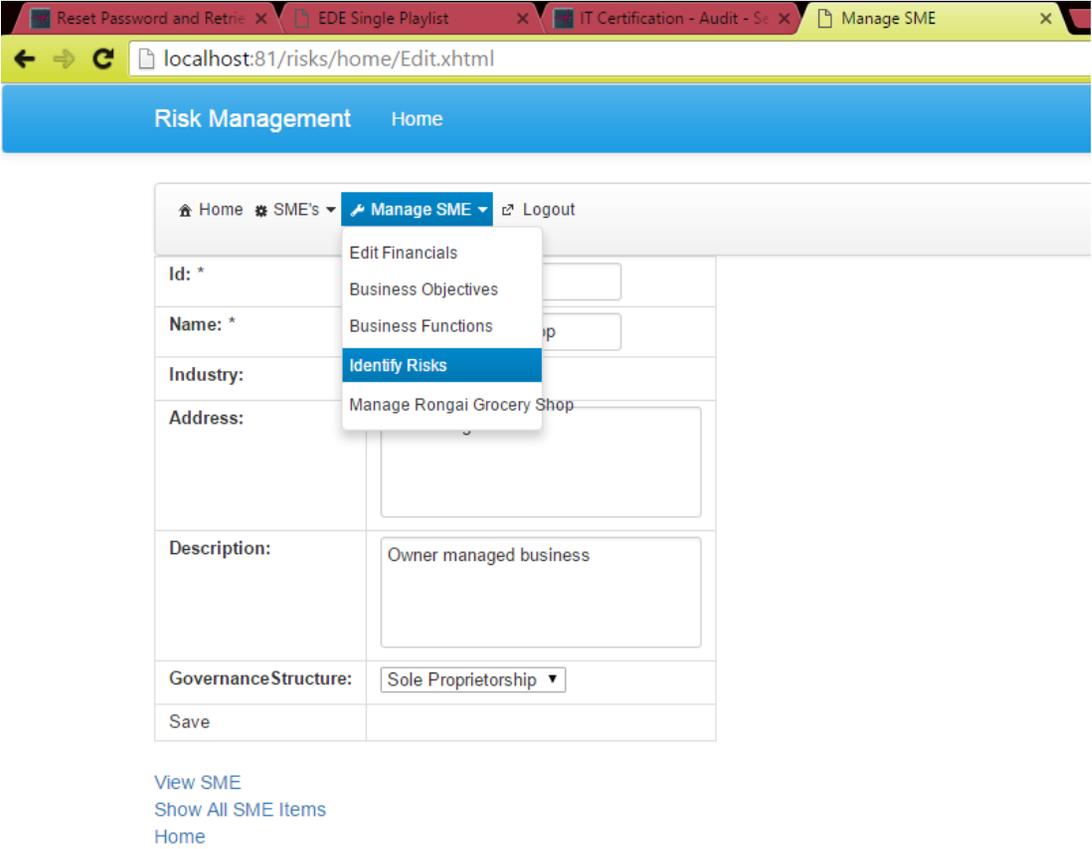
Sme:

OutSourced:

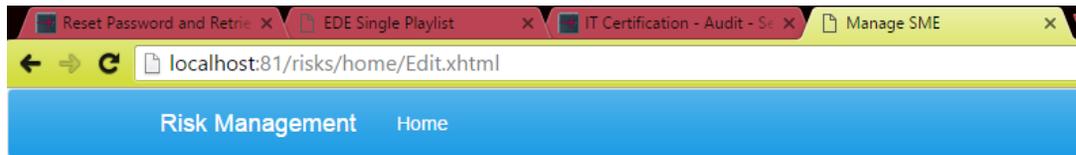
Employees:

[Save](#)

[Index](#)



Step 4: Risk Evaluation



Home SME's Manage SME Logout

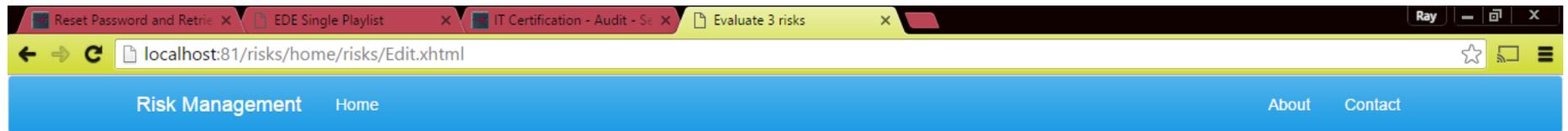
Id: *	<input type="text"/>
Name: *	<input type="text"/>
Industry:	<input type="text"/>
Address:	<input type="text"/>
Description:	<input type="text" value="Owner managed business"/>
GovernanceStructure:	<input type="text" value="Sole Proprietorship"/>
Save	

Dropdown menu items for 'Manage SME':

- Edit Financials
- Business Objectives
- Business Functions
- Evaluate Initial Risks
- Rate Risks
- Manage Rongai Grocery Shop

[View SME](#)
[Show All SME Items](#)
[Home](#)

Step 4.1: Risk Evaluation – Likelihood and Impact



Reset Password and Retri... x EDE Single Playlist x IT Certification - Audit - S... x Evaluate 3 risks x Ray

localhost:81/risks/home/risks/Edit.xhtml

Risk Management Home About Contact

Home SME's Logout	
ID	43
Risk Title	Changes in customer preferences
Risk Description	Abrupt changes in consumer preferences may arise due to various factors including changes in disposable income, availability of better substitutes, introduction of radical new technologies, and change in social standings.
Sme:	Rongai Grocery Shop
Likelihood [0 - 10] *	6
Impact on SME [0 - 10] *	7
What is your confidence level with any measures you have in place against this risk? (0 for none, 10 for perfect) *	4

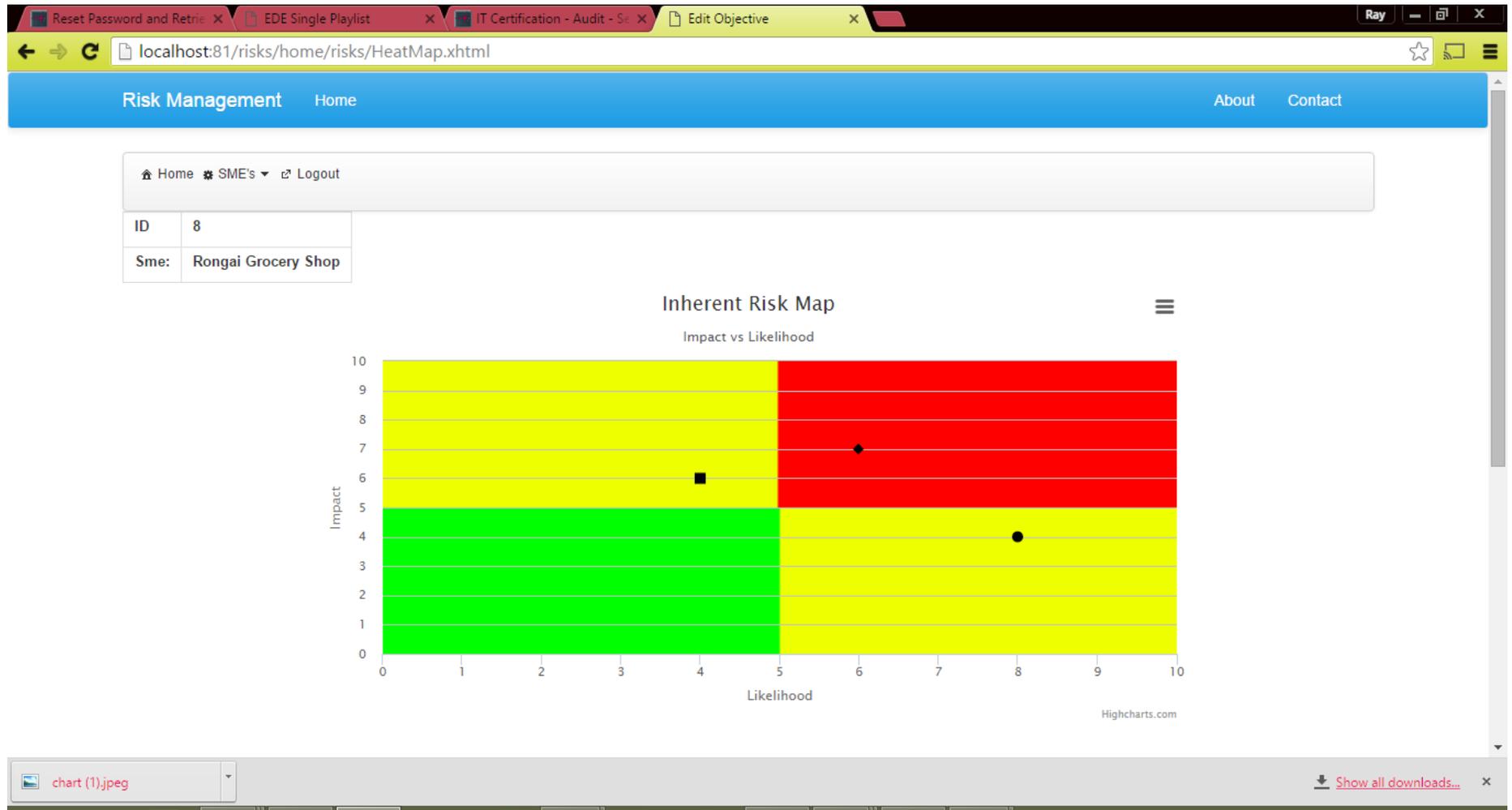
[Save Risk Data](#)
[Save and Continue](#)
[Next Risk](#)

[Manage Rongai Grocery Shop](#)
[Home](#)

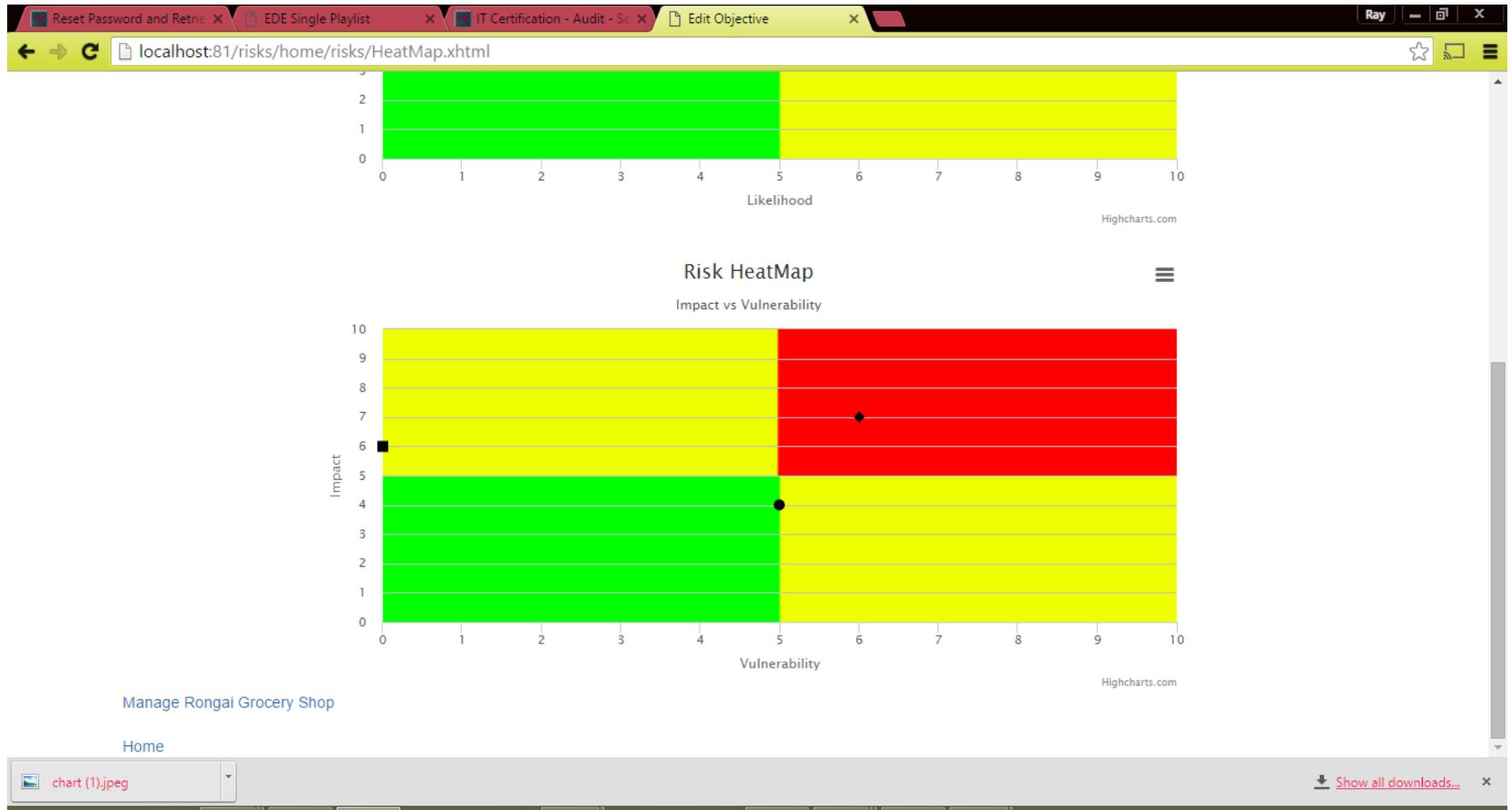
Step 5: Generate Risk Profile

The screenshot shows a web browser window with the URL `localhost:81/risks/home/Edit.xhtml`. The page has a blue header with 'Risk Management' and 'Home' on the left, and 'About' and 'Contact' on the right. Below the header is a navigation bar with 'Home', 'SME's', 'Manage SME', and 'Logout'. The 'Manage SME' dropdown menu is open, showing options: 'Edit Financials', 'Business Objectives', 'Business Functions', 'View Risk Profile' (highlighted), 'Request Risk Controls', and 'Manage Rongai Grocery Shop'. The main content area is a form with fields for 'Id: *', 'Name: *', 'Industry:', 'Address:', 'Description:' (containing 'Owner managed business'), and 'GovernanceStructure:' (set to 'Sole Proprietorship'). A 'Save' button is at the bottom of the form. Below the form are links for 'View SME', 'Show All SME Items', and 'Home'. The browser's address bar at the bottom shows `localhost:81/risks/home/Edit.xhtml#`.

Step 5.1 – Generate Risk Profile – Inherent Risk



Step 5.2: Generate Risk Profile – Residual Risk



Step 6: Risk Mitigation

The screenshot shows a web browser window with the URL `localhost:81/risks/home/Edit.xhtml`. The page has a blue header with "Risk Management" and "Home" on the left, and "About" and "Contact" on the right. Below the header is a navigation bar with "Home", "SME's", "Manage SME", and "Logout". The "Manage SME" dropdown menu is open, showing options: "Edit Financials", "Business Objectives", "Business Functions", "View Risk Profile", "Request Risk Controls" (highlighted), and "Manage Rongai Grocery Shop".

The main content area contains a form with the following fields:

- Id: *** (text input)
- Name: *** (text input)
- Industry:** (text input)
- Address:** (text input)
- Description:** (text input containing "Owner managed business")
- GovernanceStructure:** (dropdown menu with "Sole Proprietorship" selected)
- Save** (button)

Below the form are links: [View SME](#), [Show All SME Items](#), and [Home](#).

At the bottom, a file download bar shows "chart (1).jpeg" and a "Show all downloads..." link.

Step 6.1 – Risk Mitigation - Treatment

The screenshot shows a web browser window with the URL `localhost:81/risks/home/Edit.xhtml`. The browser tabs include "Reset Password and Retri...", "EDE Single Playlist", "IT Certification - Audit - S...", and "Manage SME". The page has a blue header with "Risk Management" and "Home" on the left, and "About" and "Contact" on the right. Below the header is a navigation bar with "Home", "SME's", "Manage SME", and "Logout". The "Manage SME" dropdown menu is open, showing options: "Edit Financials", "Business Objectives", "Business Functions", "View Treatments" (highlighted), "View Risk Profile", and "Manage Rongai Grocery Shop".

The main content area contains a form for editing an SME. The form fields are:

- Id:** *
- Name:** *
- Industry:**
- Address:**
- Description:** Owner managed business
- GovernanceStructure:** Sole Proprietorship
- Save**

Below the form are links: [View SME](#), [Show All SME Items](#), and [Home](#).

The bottom of the browser window shows a download bar with a file named "chart (1).jpeg" and a link to "Show all downloads...".

Step 6.2 – Risk Mitigation – Applying Suggested Treatments

The screenshot shows a web browser window with the following tabs: 'Reset Password and Retri...', 'EDE Single Playlist', 'IT Certification - Audit - S...', and 'Select Treatments'. The address bar shows 'localhost:81/risks/home/risks/Treatments.xhtml'. The main content area is titled 'Select treatments for 'Disintermediation''.

Navigation: Risks ▾

Risk Summary

item	details
name	Disintermediation
description	Suppliers, wholesalers, and retailers generate profits by charging higher prices to customers. The sourcing of product sometimes includes middlemen who charge additional fees to the end customer. An SME may fail to realize the benefits of disintermediation. The ability to reduce the number of middlemen could help reduce costs and increase profits. An SME may not be able to reap the benefits of lower input costs, and hence may not offer competitive pricing to its customers.
vulnerability	5.0
impact	4.0
likelihood	8.0

Control - Implement measures to reduce the number of middlemen to help reduce costs and increase profits

Apply

SUGGESTED

Create Custom Control

Not satisfied with our suggestions?

Custom control

Control description *

chart (1).jpeg

Show all downloads...

Step 6.3: Risk Mitigation – Accepting suggested mitigation option

The screenshot shows a web browser window with several tabs open: 'Reset Password and Retri...', 'EDE Single Playlist', 'IT Certification - Audit - S...', and 'Select Treatments'. The address bar shows 'localhost:81/risks/home/risks/Treatments.xhtml'. The page has a blue header with 'Risk Management' and 'Home' on the left, and 'About' and 'Contact' on the right. Below the header is a navigation bar with 'Home', 'SME's', and 'Logout'. The main content area is titled 'Select treatments for 'Disintermediation''. A 'Navigation' dropdown menu is open, showing 'Risks' selected, with options for 'Previous Risk' and 'Next Risk'. Below this is a 'Risk Summary' table with columns for 'item' and 'details'. The table contains the following data:

item	details
name	Disintermediation
description	Suppliers, wholesalers, and retailers generate profits by charging higher prices to customers. The sourcing of product sometimes includes middlemen who charge additional fees to the end customer. An SME may fail to realize the benefits of disintermediation. The ability to reduce the number of middlemen could help reduce costs and increase profits. An SME may not be able to reap the benefits of lower input costs, and hence may not offer competitive pricing to its customers.
vulnerability	5.0
impact	4.0
likelihood	8.0

Below the table is a text box containing the control: 'Control - Implement measures to reduce the number of middlemen to help reduce costs and increase profits'. Underneath this is a button with a checkmark icon and the text 'ACCEPTED'. The browser's download bar at the bottom shows a file named 'chart (1).jpeg' and a link to 'Show all downloads...'. The taskbar at the very bottom shows several application icons.

Reset Password and Retri... EDE Single Playlist IT Certification - Audit - Se... Select Treatments Ray

localhost:81/risks/home/risks/Treatments.xhtml

Home SME's Logout

Select treatments for 'Changes in customer preferences'

Navigation Risks

- ← Previous Risk
- Next Risk

item	details
name	Changes in customer preferences
description	Abrupt changes in consumer preferences may arise due to various factors including changes in disposable income, availability of better substitutes, introduction of radical new technologies, and change in social standings.
vulnerability	6.0
impact	7.0
likelihood	6.0

Control - Always track, monitor and assess your clients' preferences and implement measures, services and products to anticipate such

ACCEPTED

Create Custom Control

Not satisfied with our suggestions?

localhost:81/risks/home/risks/Treatments.xhtml#

chart (1).jpeg Show all downloads...

Reset Password and Retri... EDE Single Playlist IT Certification - Audit - Se... Select Treatments

localhost:81/risks/home/risks/Treatments.xhtml

Risk Management Home About Contact

Home SME's Logout

Select treatments for 'Failure to maintain credit information of customers'

Navigation Risks

Risk Summary

item	details
name	Failure to maintain credit information of customers
description	SMEs can use customer credit information to assess a new customer's credit worthiness before establishing a line of credit for that customer. If the business fails to maintain ongoing credit information of its customer base, it may not be able to prevent and mitigate financial risks of customer defaults. The process of holding credit information protects the revenue stream and helps to maintain the integrity of the SME's accounts receivables.
vulnerability	0.0
impact	6.0
likelihood	4.0

Control - Assess a new customer's credit worthiness before establishing a line of credit for that customer. At all times, maintain ongoing credit information of the SME's customer base.

ACCEPTED

Create Custom Control

chart (1).jpeg Show all downloads...

Step 7: Risk Monitoring

localhost:81/risks/home/Edit.xhtml

Risk Management Home About Contact

Home SME's Manage SME Logout

- Edit Financials
- Business Objectives
- Business Functions
- View Treatments
- View Risk Profile
- Monitor Risks**
- Manage Rongai Grocery Shop

Id: *

Name: *

Industry:

Address:

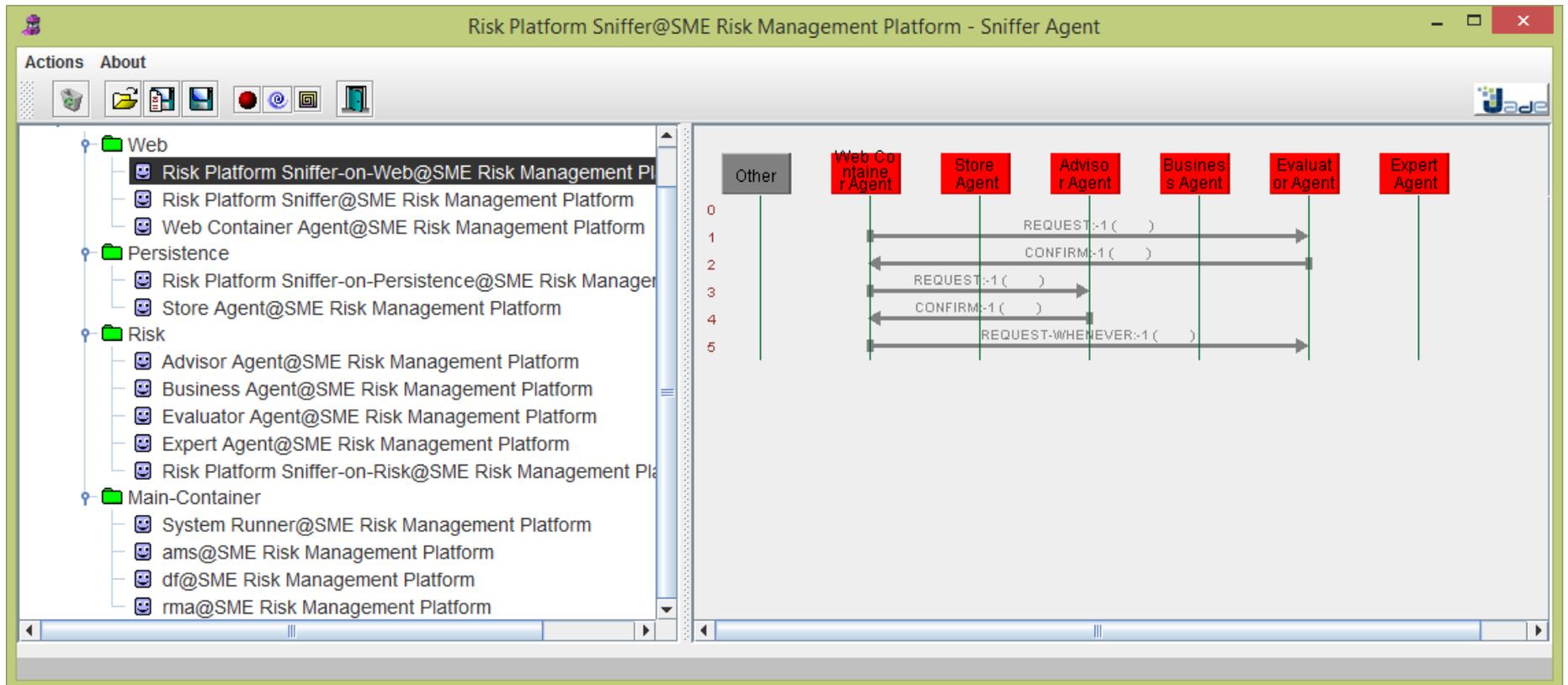
Description: Owner managed business

GovernanceStructure: Sole Proprietorship

Save

[View SME](#)
[Show All SME Items](#)
[Home](#)

chart (1).jpeg Show all downloads...



Step 8: Evaluating Status of Business Objectives

The screenshot shows a web browser window with the URL `localhost:81/risks/home/Edit.xhtml`. The page has a blue header with "Risk Management" and "Home" on the left, and "About" and "Contact" on the right. Below the header is a navigation bar with "Home", "SME's", "Manage SME", and "Logout". The "Manage SME" dropdown menu is open, showing options: "Edit Financials", "Business Objectives", "Business Functions", "Evaluate Objectives" (highlighted), "Rate Risks", and "Manage Rongai Grocery Shop".

The main content area contains a form for editing an SME. The form fields are:

- Id:** *
- Name:** *
- Industry:**
- Address:**
- Description:** Owner managed business
- GovernanceStructure:** Sole Proprietorship
- Save**

Below the form are links: [View SME](#), [Show All SME Items](#), and [Home](#).

The browser's download bar at the bottom shows a file named "chart (1).jpeg" and a link to "Show all downloads...".

Step 8.1: Evaluating Status of Business Objectives

Reset Password and Retri... x EDE Single Playlist x IT Certification - Audit - S... x Edit Monitored Objective x

localhost:81/risks/home/risks/Objectives.xhtml

Risk Management Home About Contact

Home SME's Logout

Objective updated:

ID	21
Objective Title	Realize maximum margin for sales made
Sme:	Rongai Grocery Shop
	Please note, the value for the objective is a comparative value. 100% is assigned to the original value of the objective, at the beginning of the risk management cycle
Objective value % *	<input type="text" value="50.0"/>

[Save Objective](#)

[Manage Rongai Grocery Shop](#)
[Home](#)

chart (1).jpeg Show all downloads...

Step 9: Evaluating Risk Status - Updated Risk Profile

Reset Password and Retrie... x EDE Single Playlist x IT Certification - Audit - S... x Edit Objective x Ray

localhost:81/risks/home/risks/HeatMap.xhtml

ID	8
Sme:	Rongai Grocery Shop

Inherent Risk Map

Impact vs Likelihood

Impact

Likelihood

Highcharts.com

Risk HeatMap

Impact vs Vulnerability

Impact

Vulnerability

Highcharts.com

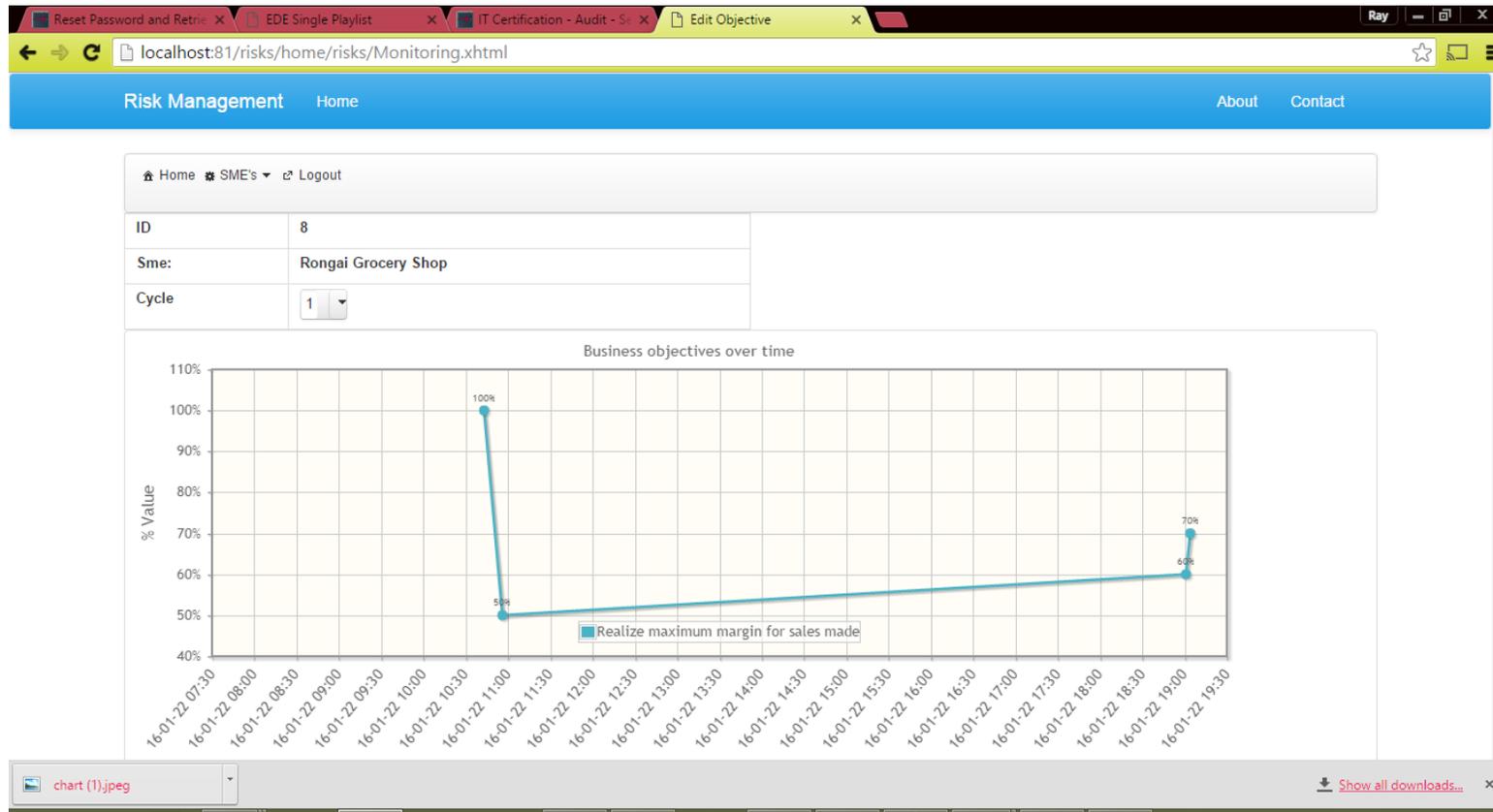
[Manage Rongai Grocery Shop](#)

[Home](#)

chart (1).jpeg

Show all downloads...

Step 10: Monitoring Trend in Business Objectives



Home SME's Logout

Id	Category	Title	Sme	Value	Date Updated	
18	Grow Margins	Realize maximum margin for sales made	Rongai Grocery Shop	70%	01/22/2016 10:41:02	View Edit Destroy
19	Reduce Losses	Effectively manage expenses and tighten margins	Rongai Grocery Shop	20	01/22/2016 19:08:38	View Edit Destroy
20	Grow Scale	Ensure growth in operations, capital and sphere	Rongai Grocery Shop	50	01/22/2016 19:08:52	View Edit Destroy

[Create New Objective](#)

[Index](#)

APPENDIX C: SAMPLE PROGRAM CODE

The following is the source code for the MAS Risk Management Platform for SMEs in Kenya

JadeRunner.java

```
package ray.sme.risk;

import com.seaglasslookandfeel.SeaGlassLookAndFeel;

import jade.core.Profile;

import jade.core.ProfileImpl;

import jade.wrapper.AgentContainer;

import jade.wrapper.ControllerException;

import java.util.logging.Level;

import java.util.logging.Logger;

import javax.swing.UnsupportedLookAndFeelException;

import ray.sme.risk.agents.SystemRunnerAgent;

import ray.sme.risk.utils.DefaultUserCreator;

public class JadeRunner {

    /**
     * @param args the command line arguments
     */

    public static void main(String[] args) {

//    try {

//        javax.swing.UIManager.setLookAndFeel(new SeaGlassLookAndFeel());

//    } catch (UnsupportedLookAndFeelException ex) {

//        Logger.getLogger(JadeRunner.class.getName()).log(Level.SEVERE, null, ex);

//    }

        DefaultUserCreator.main(args);
    }
}
```

```
try {
    Profile profile = new ProfileImpl("localhost", 1099,
        Profile.PLATFORM_ID);
    profile.setParameter(Profile.PLATFORM_ID, "SME Risk Management Platform");
    profile.setParameter("gui", "true");
    AgentContainer container = jade.core.Runtime.instance().createMainContainer(profile);
    try {
        container.start();
        container.createNewAgent(SystemRunnerAgent.SYSTEM_RUNNER_AGENT,
SystemRunnerAgent.class.getName(),
            null).start();
    } catch (ControllerException ex) {
        ex.printStackTrace();
    }
} catch (Exception ex) {
    ex.printStackTrace();
}
```

WebInterfaceAgent.java

```
package ray.sme.risk.agents;

import jade.core.AID;
import jade.core.Agent;
import jade.core.behaviours.OneShotBehaviour;
import jade.core.behaviours.TickerBehaviour;
import jade.lang.acl.ACLMessage;
import java.io.IOException;
import java.lang.management.ManagementFactory;
import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Map;
import java.util.Objects;
import java.util.concurrent.ConcurrentLinkedQueue;
import java.util.logging.Level;
import java.util.logging.Logger;
import org.eclipse.jetty.jmx.MBeanContainer;
import org.eclipse.jetty.server.Server;
import org.eclipse.jetty.util.component.Container;
import org.eclipse.jetty.webapp.WebAppContext;
import org.slf4j.LoggerFactory;
import ray.sme.risk.agents.ontology.RiskIdentificationRequestsWrapper;
import ray.sme.risk.agents.ontology.RiskTreatmentRequestsWrapper;
import ray.sme.risk.objects.BaseEntity;
import ray.sme.risk.objects.ObjectManager;
import ray.sme.risk.objects.monitoring.MonitoringCycle;
```

```

import ray.sme.risk.objects.monitoring.MonitoringStage;

import ray.sme.risk.objects.sme.analysis.Analysis;

import ray.sme.risk.objects.sme.analysis.AnalysisStatus;

public class WebInterfaceAgent extends AbstractAgent {

    private static long SLEEP = 0;

    private static ConcurrentLinkedQueue<ObjectManager.WRAPPER> rqs;

    final Server server;

    public static void queue(ObjectManager.WRAPPER wr) {

        rqs.add(wr);

    }

    public WebInterfaceAgent() {

        rqs = new ConcurrentLinkedQueue<>();

        server = new Server(81);

    }

    @Override

    protected void setup() {

        checkSleep();

        AID[] services = getServices(getClass().getSimpleName());

        boolean start = true;

        if (services != null) {

            if (services.length > 0) {

                start = false;

            }

        }

        super.setup();

        if (start) {

            //      addBehaviour(new TreatmentRequestHandler(3000l));

```

```

        addBehaviour(new RQHandler(1));
//        addBehaviour(new RiskIdentifier(3000l));
        addBehaviour(new WebContainerHandler());
    } else {
        try {
            doDelete();
        } catch (Exception e) {
        }
    }
}

@Override
protected void takeDown() {
    try {
        server.stop();
    } catch (Exception e) {
    }

    super.takeDown(); //To change body of generated methods, choose Tools | Templates.
}

private static synchronized void checkSleep() {
    try {
        Thread.sleep(SLEEP * 1000l);
    } catch (InterruptedException ex) {
        Logger.getLogger(WebInterfaceAgent.class.getName()).log(Level.SEVERE, null, ex);
    }

    if (SLEEP <= 0) {
        SLEEP++;
    }
}

```

```

}

private class WebContainerHandler extends OneShotBehaviour {

    @Override

    public void action() {

        new Thread(new Runnable() {

            @Override

            public void run() {

                try {

                    MBeanContainermbContainer=new
MBeanContainer(ManagementFactory.getPlatformMBeanServer());

                    server.addBean(mbContainer);

                    org.eclipse.jetty.webapp.Configuration.ClassList classlist =
org.eclipse.jetty.webapp.Configuration.ClassList.getServerDefault(server);

                    classlist.addAfter("org.eclipse.jetty.webapp.FragmentConfiguration",
"org.eclipse.jetty.plus.webapp.EnvConfiguration", "org.eclipse.jetty.plus.webapp.PlusConfiguration");

                    WebApplicationContext webapp = new WebApplicationContext();

                    webapp.setContextPath("/");

                    webapp.setWar("war/Web.war");

                    webapp.setInitParameter("org.eclipse.jetty.servlet.Default.dirAllowed", "false");

                    server.setHandler(webapp);

//                    org.eclipse.jetty.plus.jndi.Transaction transactionMgr = new
org.eclipse.jetty.plus.jndi.Transaction(new com.acme.MockUserTransaction());

                    server.setStopAtShutdown(true);

                    server.start();

                    server.join();

                } catch (Exception ex) {

                    log.error(" action -- error starting server ", ex);

                    doDelete();

                }
            }
        })
    }
}

```

```

    }
    }, "Server Thread Blocking").start();
}
}

private final class RiskIdentifier extends TickerBehaviour {
    private final org.slf4j.Logger log;

    public RiskIdentifier(long period) {
        super(WebInterfaceAgent.this, period);
        this.log = LoggerFactory.getLogger(getClass());
        log.info(" RiskIdentifier.constructor -- { } ", getClass().getSimpleName());
    }

    @Override
    protected void onTick() {
        log.debug(" onTick -- checking SMEs for risk identification ");

        Map<String, Object> map = new HashMap<>();

        String q = "SELECT p FROM Analysis p WHERE p.analysisStatus = :risksIdentified AND
p.stageStatus = :stage";

        map.put("risksIdentified", AnalysisStatus.RiskIdentification);
        map.put("stage", Boolean.FALSE);

        List<BaseEntity> findAnalyses = getObjectManager().findEntities(q, map);

        if (findAnalyses.isEmpty()) {
            log.debug(" onTick -- No SME's to identify risks ");
        } else {
            log.debug(" onTick -- { } SME's need risk identification ", findAnalyses.size());

            ArrayList<Analysis> a = new ArrayList();

            for (BaseEntity an : findAnalyses) {
                Analysis analysis = (Analysis) an;
                analysis.setStageStatus(null);
            }
        }
    }
}

```

```

        a.add(analysis);

        getObjectManager().save(analysis);
    }

    RiskIdentificationRequestsWrapper rw = new RiskIdentificationRequestsWrapper();

    rw.setAnalyses(a);

    ACLMessage msg = new ACLMessage(ACLMessage.REQUEST);

    try {

        msg.setContentObject(rw);

        msg.addReceiver(new AID(EVALUATOR_AGENT, AID.ISLOCALNAME));

        send(msg);

    } catch (IOException ex) {

        log.error(" onTick -- error sending message", ex);

    }

}

}

}

private final class TreatmentRequestHandler extends TickerBehaviour {

    private final org.slf4j.Logger log;

    public TreatmentRequestHandler(long period) {

        super(WebInterfaceAgent.this, period);

        this.log = LoggerFactory.getLogger(getClass());

        log.info(" TreatmentRequestHandler.constructor -- {} ", getClass().getSimpleName());

    }

    @Override

    protected void onTick() {

        log.debug(" onTick -- checking SMEs for risk treatment suggestions ");

        Map<String, Object> map = new HashMap<>();

```

```

String q = "SELECT p FROM MonitoringCycle p WHERE p.simpleStage = :stage AND
p.selectItem = :selectItem";

map.put("stage", MonitoringStage.TREATMENTS_REQUESTED);

map.put("selectItem", Boolean.TRUE);

List<BaseEntity> findAnalyses = getObjectManager().findEntities(q, map);

if (findAnalyses.isEmpty()) {

    log.debug(" onTick -- No SME's to suggest treatment of risks ");

} else {

    log.debug(" onTick -- {} SME's need treatment suggestions ", findAnalyses.size());

    ArrayList<Analysis> a = new ArrayList();

    for (BaseEntity an : findAnalyses) {

        MonitoringCycle analysis = (MonitoringCycle) an;

        analysis.setSimpleStage(null);

        a.add(analysis.getAnalysis());

        analysis.setSelectItem(Boolean.FALSE);

        getObjectManager().save(analysis);

    }

    RiskTreatmentRequestsWrapper rw = new RiskTreatmentRequestsWrapper();

    rw.setAnalyses(a);

    ACLMessage msg = new ACLMessage(ACLMessage.REQUEST);

    try {

        msg.setContentObject(rw);

        msg.addReceiver(new AID(ADVISOR_AGENT, AID.ISLOCALNAME));

        send(msg);

    } catch (IOException ex) {

        log.error(" onTick -- error sending message", ex);

    }

}

```

```

    }
}

private class RQHandler extends TickerBehaviour {

    public RQHandler(long seconds) {

        super(WebInterfaceAgent.this, seconds * 1000l);

    }

    @Override

    protected void onTick() {

        ObjectManager.WRAPPER wr;

        while ((wr = rqs.poll()) != null) {

            if (wr.getEntity().getClass().equals(MonitoringCycle.class)) {

                MonitoringCycle m = (MonitoringCycle) wr.getEntity();

                boolean processed = false;

                if (wr.getAction() == ObjectManager.ACTION.LOGIN) {

                    if (m.getCycleNumber() > 1) {

                        //subsequent monitoring

                        //forward to evaluation agent

                        ACLMessage ac = new ACLMessage(ACLMessage.REQUEST_WHENEVER);

                        ac.addReceiver(new AID(BUSINESS_AGENT, AID.ISLOCALNAME));

                        processed = true;

                        try {

                            ac.setContentObject(m);

                            send(ac);

                        } catch (IOException ex) {

                            Logger.getLogger(WebInterfaceAgent.class.getName()).log(Level.SEVERE, null, ex);

                        }

                    }

                }

            } else if (wr.getAction() == ObjectManager.ACTION.INSERT) {

```

```

if (m.getCycleNumber() > 1) {
    //subsequent monitoring
    //forward to evaluation agent
    ACLMessage ac = new ACLMessage(ACLMessage.REQUEST_WHENEVER);
    ac.addReceiver(new AID(EVALUATOR_AGENT, AID.ISLOCALNAME));
    processed = true;
    try {
        ac.setContentObject(m);
        send(ac);
    } catch (IOException ex) {
        Logger.getLogger(WebInterfaceAgent.class.getName()).log(Level.SEVERE, null, ex);
    }
}
}

if (!processed) {
    if (m.getSimpleStage() == MonitoringStage.TREATMENTS_REQUESTED &&
Objects.equals(m.getSelectItem(), true)) {
        RiskTreatmentRequestsWrapper rw = new RiskTreatmentRequestsWrapper();
        ArrayList<Analysis> a = new ArrayList<>();
        a.add(m.getAnalysis());
        rw.setAnalyses(a);
        ACLMessage msg = new ACLMessage(ACLMessage.REQUEST);
        try {
            msg.setContentObject(rw);
            msg.addReceiver(new AID(ADVISOR_AGENT, AID.ISLOCALNAME));
            send(msg);
        } catch (IOException ex) {
            log.error(" onTick -- error sending message", ex);

```


BusinessAgent.java

```
package ray.sme.risk.agents;

import java.util.ArrayList;

import java.util.List;

import ray.sme.risk.agents.behaviours.AutoResponder;

import ray.sme.risk.objects.ObjectManager;

import ray.sme.risk.objects.authentication.SystemUser;

public class BusinessAgent extends AbstractAgent{

    @Override

    protected void setup() {

        super.setup(); //To change body of generated methods, choose Tools | Templates.

        List<AutoResponder.Filter> items = new ArrayList<>();

        AutoResponder.Filter f = new AutoResponder.Filter(SystemUser.class,

ObjectManager.ACTION.LOGIN);

        items.add(f);

        addBehaviour(new AutoResponder(items, this));

    }

}
```

AutoResponder.java

```
package ray.sme.risk.agents.behaviours;

import jade.core.Agent;

import jade.core.behaviours.CyclicBehaviour;

import jade.lang.acl.ACLMessage;

import jade.lang.acl.MessageTemplate;

import java.io.Serializable;

import java.util.List;

import java.util.Objects;
```

```

import ray.sme.risk.objects.BaseEntity;

import ray.sme.risk.objects.ObjectManager;

/**
 *
 * @author tindase
 */

public class AutoResponder extends CyclicBehaviour {

    private final List<Filter> items;

    private MessageTemplate messageTemplate;

    public AutoResponder(List<Filter> items, Agent a) {

        super(a);

        this.items = items;

        messageTemplate = MessageTemplate.MatchPerformative(ACLMessage.REQUEST_WHENEVER);

    }

    @Override

    public void action() {

        ACLMessage receive = myAgent.receive(messageTemplate);

        try {

            Serializable contentObject = receive.getContentObject();

            if (contentObject instanceof ObjectManager.WRAPPER) {

                ObjectManager.WRAPPER wr = (ObjectManager.WRAPPER) contentObject;

                for (Filter item : items) {

                    if (Objects.equals(wr.getAction(), item.ACTION_TYPE)

                        && item.type.isInstance(wr.getEntity())) {

                        ACLMessage createReply = receive.createReply();

                        createReply.setContent("OK");

                        createReply.setPerformative(ACLMessage.CONFIRM);
                    }
                }
            }
        }
    }
}

```

```
        myAgent.send(createReply);
    }
}
}
} catch (Exception e) {
}
}

public static class Filter {
    private Class type;
    private ObjectManager.ACTION ACTION_TYPE;
    public Filter(Class type, ObjectManager.ACTION ACTION_TYPE) {
        this.type = type;
        this.ACTION_TYPE = ACTION_TYPE;
    }
}
}
}
```